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SOVIET SOIL SCIENCE

7

JULY 1960

A TRANSLATION
OF POCHVOVEDENIYE



AMERICAN INSTITUTE
OF BIOLOGICAL SCIENCES
2000 P STREET, N.W.
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THE translation and publication of this and other Russian language biological journals and monographs is a project of the American Institute of Biological Sciences. This project is supported by grants from the National Science Foundation. Each publication is a cover-to-cover translation of its Soviet counterpart and the contents are only those of the original authors.

Pochvovedeniye in English translation bears the Soviet issue numbers. The Soviet journal carries no volume numbers. Translation begins with Number 1, the January 1958 issue. It is published in the same number of issues per year as the original Soviet journals: 12 issues.

translated and produced by
ROYER & ROGER, INC.
INTERNATIONAL DIVISION



Subscription Prices:

\$40.00 per year, individuals and industrial libraries
20.00 per year, university and non-profit libraries
3.00 additional to each price for foreign orders
4.50 each, single copies

Order from:

American Institute of Biological Sciences
2000 P Street, N.W., Washington 6, D.C.

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SOVIET SOIL SCIENCE

A translation of the monthly journal—*POCHVOVEDENIYE*—
a publication of the V. V. Dokuchayev Institute of Soil Science,
Academy of Sciences, USSR. A journal founded in 1899.

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No. 7: July 1960

Translation printed: August 1961

CONTENTS

	Page	Russian Page
100TH ANNIVERSARY OF THE BIRTH OF NIKOLAY MIKHAYLOVICH SIBIRTSEV, by I. V. Tyurin	691	1
THE LIFE AND WORK OF NIKOLAY MIKHAYLOVICH SIBIRTSEV, by S. S. Sobolev	693	3
THE WORK OF N. M. SIBIRTSEV ON THE CLASSIFICATION AND MAPPING OF SOILS, by Ya. A. Liverovski	697	8
THE ROLE OF N. M. SIBIRTSEV IN THE ESTABLISHMENT OF EXPERI- MENTAL FIELDS IN THE NIZHNIY NOVGOROD GOVERNMENT, by V. Shubin	701	14
ODZOLIC-BOG SOILS, by D. M. Rybtsov	705	20
OLIAN MEADOW-STEPPE SOLONETZ COMPLEXES OF THE MIDDLE IRTYSH REGION, by A. A. Sokolov, R. Dzhapaisov, and N. L. Kotin	715	32
SOIL FORMATION PROCESSES AND THE CLASSIFICATION OF FLOOD- PLAIN SOILS IN THE STEPPE ZONE OF THE CENTRAL CHER- NOZEM BELT, by Ye. P. Voronova	724	43
CHEMICAL AND MINERALOGICAL CHARACTERIZATION OF SOILS IN THE CENTRAL PART OF THE KARELIA ISTHMUS, by B. P. Gradusov	731	53
CHANGE IN SOIL MELIORATIVE CONDITIONS AFTER DIKING THE VOLGA-AKHTUBA FLOOD PLAIN, by A. A. Popov	739	63
INCREASING THE EFFECTIVENESS OF THE RESIDUAL EFFECT OF PHOSPHOROUS FERTILIZERS, by P. A. Dmitrenko and L. A. Shevchenko	748	74
INFLUENCE OF POTASSIUM FERTILIZERS ON THE YIELD OF HAY AND ALFALFA ROOTS ON MEADOW SOILS IN THE IRRIGATED ZONE OF CENTRAL ASIA, by M. Z. Kaziyeu and Kh. Z. Umarov	753	81
CHARACTERISTICS OF CERTAIN SOILS OF THE PSKOV OBLAST', by O. V. Butuzova	758	87

	Page	Russian Page
METHODS		
THE LOWER LIMIT OF AVAILABLE MOISTURE FOR PLANTS IN PEAT SOILS, by F. R. Zaydel'man and V. G. Vinogradov	765	96
COMPARATIVE STUDY OF METHODS OF DETERMINING WATER-PERME- ABILITY UNDER CONDITIONS OF SOD-PODZOLIC SOILS OF THE MOSCOW OBLAST', by Kao Ch'eng-min	770	101
INFLUENCE OF VARIOUS CONCENTRATIONS OF GASEOUS OXYGEN IN THE AIR OF THE SOIL ON OXIDATION-REDUCTION CONDITIONS, by I. P. Grechin and Ch'eng Hsiung-sheng	775	106
PROBLEM OF CALCULATING THE WIDTH OF FOREST SHELTERBELTS FOR EROSION CONTROL, by I. I. Starchenko	779	110
THE PHENOMENON OF IMPULVERIZATION IN THE AREA OF ELISTA, by V. S. Shumakov and A. I. Mikhovich	781	112
REVIEW		
RECLAMATION OF VIRGIN LAND IN THE SEMI-DESERT, by S. K. Chayanov	783	114
OBITUARY		
IVAN FEDOROVICH STRANSKIY (APRIL 18, 1886-OCTOBER 29, 1959), by Collective of the Soil Institute of the Bulgarian Academy of Sciences, and Editorial Staff of Pochvovedeniye	785	116
BIBLIOGRAPHY	787	118

100TH ANNIVERSARY OF THE BIRTH OF NIKOLAY MIKHAYLOVICH SIBIRTSEV¹

V. TYURIN

In 1960 Soviet scientists celebrate the 100th anniversary of the birth of the outstanding Russian soil scientist, Nikolay Mikhaylovich Sibirtsev, the closest student and co-worker of Dokuchayev, who created, together with the latter, the new Dokuchayev soil science.

Nikolay Mikhaylovich Sibirtsev died before his time at the age of forty of a severe lung illness, at the height of his busy scientific and teaching career. Nevertheless, in spite of his relatively short period of activity, Nikolay Mikhaylovich left a deep and lasting impression on the history of our science, which owes him master works in the study of the soils of the former Nizhny Novgorod Government, outstanding in its importance, classification of soils, and the excellent course on "Soil Science," which served as a text for and converted to soil science several generations of soil scientists and agronomists, and which has not lost its interest and educational value on a number of subjects to this day.

It may be said that, if the founder of modern soil science, V. V. Dokuchayev, outlined the brilliant project of the contents of the new science, his talented, industrious and consistently premitting student and worker, N. M. Sibirtsev, embodied the project into the final, carefully finished form of a systematic course, in which the new ideas advanced by Dokuchayev were presented in a sound combination with the rich empirical material collected by that time by West European and native (P. A. Kostychev and other) scientists, including N. M. Sibirtsev himself.

When one reads his "Soil Science," one cannot refrain from a feeling of delight at the correct interpretation of many problems, with a true sense of observation, as a result of which Nikolay Mikhaylovich was able to anticipate many modern concepts.

A number of examples follow.

1. The formation of podzol was explained by N. M. Sibirtsev as a result of the influence of free humic acids, infiltrating with atmospheric waters from the upper layers, as well as to the temporary presence of reduction processes in which ferric oxide changes into a mobile ferrous state.

2. In sub-dividing podzolic soils he made a distinction between sod soils, slightly (or imperceptibly) touched by podzol-forming processes, podzolic soils as such with a clearly defined podzolic horizon, and podzols, or strongly podzolic soils (often to the surface). He also paid attention to the properties of podzols in flat depressions, or flat, enclosed areas with stagnant moisture, which he called by the local names of "ilovka" and gleyey soils. In these soils we easily recognize the modern pseudo-gleyey soils (or podzols with gley at the surface).

An interesting remark made by N. M. Sibirtsev is that the podzolic horizon of loess-like clay loam is usually yellowish. This feature, as known, is characteristic of the sod-podzolic clay loam-like soils of Belorussia and Middle European plains, which were later called pale yellow sod-podzolic soils (or sol lessivé).

The severely scientific style of writing of N. M. Sibirtsev did not interfere with a certain scientifically-based phantasy, which made it more lively, more convincing, and interesting. He himself commented on that, as his friend, Professor P. F. Barakova reported: "When I work, I feel like an artist; pictures of the past appear in my mind and I want to describe them in a manner which would be clear and understandable to others."

As an example of such a work of imagination, I would like to mention certain considerations of Sibirtsev on the origin of gray forest lands.

"It is very probable that the zone of these soils, as well as that of chernozem, was at one time occupied by grass vegetation, was an ancient and 'pre-historic steppe' (G. N. Tanfil'yev); but it rapidly fell under the influence of forests and the conditions of soil formation changed. Under the remaining steppe they remained as they were, 'grassy,' and became mature chernozem; here under the ancient steppe, rapidly overgrown by forests, they followed another

¹Introductory address of I. V. Tyurin at the meeting of the All-Union Society of Soil Scientists and the Scientific Council of the V. V. Dokuchayev Soil Science Institute. Academy of Sciences. USSR.

direction and became forest soils.

"The discordance of soil formation is the factor which separated these soils from chernozem. The sooner it happened, the greater the difference in soils; the later it happened, the farther chernozem followed the course of independent development and the less it could be subjected to the influence of a new factor."

How clearly, convincingly, and unusually it is stated! It is unusual because the difference between gray forest soils and chernozem is explained not as much as a result of the prolonged

influence of forests on the already-formed chernozem (as S.I. Korzhinskiy and others do), but as a result of the prolonged effect of grasses on ancient pre-chernozem (and pre-gray forest soils), which led to the formation of mature chernozem or, in the case of a more late development of forests, to the formation of dark-gray forest soils, or degraded chernozem.

The name of Nikolay Mikhaylovich Sibirtsev, the talented scientist, the closest student and co-worker of the great Dokuchayev, and one of the founders of scientific soil science, will always live in the history of our science.

THE LIFE AND WORK OF NIKOLAY MIKHAYLOVICH SIBIRTSEV 1

S. SOBOLEV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

When we re-read the works of Nikolay Mikhailovich Sibirtsev, and when we become acquainted with his letters to V. V. Dokuchayev, we form a certain image of this scientist as an incorruptible fighter and founder of the new genetic soil science, a brilliant and accurate investigator, and a talented teacher. This was a man who was very demanding of himself, not remitting in work to the degree of severity, who could stand personal deprivations and all drawbacks and failures of the new science, who fearlessly told the truth (which was not always pleasant, but good for the work) to his superior and even to his teacher and friend, V. V. Dokuchayev. This hard-working man, who trained himself from his early years for continuous scientific work, wrote more than 80 publications during his short life time (40 years), including a series of large monographs and the textbook "Soil Science," which is rightly considered to be a classic. Sibirtsev worked without relent, with intensity, without regard for his health. He made the last correction on "Soil Science" three days before his death. Due to the degree of being shy, Sibirtsev felt that he was unworthy of being a teacher, although he already had a great name as an investigator, and for a long time, in spite of the assistance of V. V. Dokuchayev, would not occupy the professorial chair at the Novo-Aleksandriya Institute of Agriculture and Forestry. In Sibirtsev's letters, in which he writes Dokuchayev about his understanding of professorial duties and requirements which must be set for professors, are remarkable. By reading these beloved letters, the minutes of the meetings of scientific societies, newspapers, journals, and becoming acquainted with the scientific disputes of that time, the present generation may obtain a picture, even if it is general, of the life and working conditions of scientists, the creators of the second half of the nineteenth century.

N. M. Sibirtsev was born on February 13, 1860, in Arkhangel'sk. He obtained his secondary education in the theological seminary in Arkhangel'sk, where his father taught natural sciences and agriculture. After graduating from St. Petersburg University in 1882, Sibirtsev

was invited by V. V. Dokuchayev to take part in the investigation of the soils of Nizhny Novgorod Government. Thereafter, he devoted all his time to soil science, working together with Dokuchayev.

After finishing the work in Nizhny Novgorod Government, Sibirtsev, at the request of V. V. Dokuchayev, began organizing the first Russian Zemstvo Museum of Natural History at Nizhny Novgorod in 1885. He studied the nature of the region, and propagated natural sciences and agriculture among the local population.

In the same period, beginning in 1887, Sibirtsev continued his work on the site quality of soils, taking part in district evaluation of the Nizhny Novgorod Government council. It was characteristic of both Sibirtsev and Dokuchayev that they did not think the work of soil scientists to be finished after a soil map was compiled. Sibirtsev tried to characterize agronomically every soil, every textural type, and every soil group according to the parent material. He studied the characteristics of soils with the object of determining their agricultural value (site quality) under a definite agricultural level, in order to mark the ways for the future increase of yield.

In order to finish the economical part of the site quality studies by Nizhny Novgorod Government and be able to make conclusions on the distribution of normal yields within a county, materials collected by the Dokuchayev expedition in Nizhny Novgorod were insufficient. Additional and more detailed soil investigations had to be made, and without stopping his work at the Museum, Sibirtsev took on these investigations. He constructed a new and more detailed site quality scale, which allowed evaluation of 18 different soils, instead of the earlier 8. A comparison of the evaluations made according to the major soil indices (which determine their fertility under given conditions) with statistical data on yield, obtained for a number of estates, with similar types of predominant soil, gave good results. When the fields were in the same state of cultivation, the site quality of soils and relative yield agreed almost completely.

N. M. Sibirtsev worked out a program for agronomically characterizing soils, in which he required that the best, medium, and poor land be identified, on the basis of questionnaires sent

Given at the Soil Institute, Academy of Science, USSR, and All-Union Society of Soil Scientists on March 9, 1960, the anniversary of the birth of N. M. Sibirtsev.

to land owners, and put under the most widely used agricultural crops, such as wheat, flax, oat, etc. The program required that new, old plowed, heavily and slightly fertilized, and non-fertilized land, non-plowed and bog areas be identified. It was required that the physical properties of soils be studied in the field (for instance, for wettability, rapid drying, the formation of fissures and crusts) and related to the sogging and burning of crops.

Sibirtsev paid great attention to the experience of people, and the first question he raised in describing soils was that of what soils are being differentiated by farmers. The data obtained by him from that collected by practical farmers are of special value because Sibirtsev translated them at once into the scientific language of a soil scientist.

The works of Sibirtsev on the agronomical characterization and site quality of soils are not obsolete to this day. The first All-Union meeting on the site quality and agronomical characterization of soils in December 1959 resolved to use as the basis for modern soil valuation the principles of Dokuchayev and Sibirtsev, as adapted to the conditions of modern socialistic agriculture.

N. M. Sibirtsev did not limit himself to the construction of a site quality index for soils of Nizhny Novgorod Government, he observed how soils of a given site quality change in productivity in dry years. The drought and poor yield of 1891, as Sibirtsev writes, upturned the scale of normal soil productivity and quality. The best clay loam and clay mountain chernozem, which, on the average, yielded 13-14 ctnr/ha of rye, yielded only 1.8 ctnr/ha during the drought of 1891, that is, yield diminished 8.3 times, while sandy and sandy loams, where the average yield of rye was 7 ctnr/ha, yielded 3 ctnr/ha during the drought, or 2.3 times less. Thus, the investigations of Sibirtsev confirmed the long-standing opinion of farmers that sandy soils give a crop even during droughts.

During the same period, Sibirtsev was commissioned by the Geological Committee to conduct geological investigations in Nizhny Novgorod and surrounding Governments. The results of the investigations, in the form of the monograph "Oka-Klyaz'ma Basin; Geological outline" (1896), served as his Master's thesis. During his investigations, Sibirtsev found a succession of Permian-carbonaceous deposits and proved the absence of a break between deposits of the Carbonic and Permian periods in the entire territory.

The unusual drought and famine of 1891 prompted Sibirtsev to raise the problem before the Nizhny Novgorod Government council of the organization in the Government of a network of experimental fields and meteorological stations for properly working out the problem of drought control. When in 1892 Dokuchayev succeeded in organizing "A special expedition of the Department of Forestry," Sibirtsev occupied the position of leader of the expedition. Together with Dokuchayev they worked out in detail a general plan for the control of droughts, dry winds, erosion and other agricultural calamities. This detailed plan was published under the joint

authorship of V. V. Dokuchayev and N. M. Sibirtsev in the Works of the expedition.

The plan of Dokuchayev and Sibirtsev, supplemented by V. R. Vil'yams, was fully put into effect in Kamennaya Steppe in the Voronezh Oblast'. This plan withstood with honors the test of the severe drought of 1946 and has retained its importance to this day. In 1946 precipitation in the Voronezh Oblast' was even less than during the drought of 1891. However, even if in the surrounding kolkhozes crop yield was 3 ctnr/ha at best, that in the Kamennaya Steppe reached 16.5 ctnr/ha (15 — for winter rye, 10.6 — for spring wheat, 15.8 — for oat, and 21.2 — ctnr/ha for sunflower).

In 1894, N. M. Sibirtsev was given the Chair of Soil Science in the Novo-Aleksandriya Institute of Agriculture and Forestry. This was the first Chair for the new Russian science, genetic soil science, which was approved by V. V. Dokuchayev, who during this period was the head of the Novo-Aleksandriya Institute. Sibirtsev organized a soil laboratory, where students studied methods of soil analysis, participating in the creative work of the Chair.

From 1895 on, Sibirtsev supervised soil investigations in Pskov Government and personally studied Opochets district. In the same year he exhibited his soil collection and maps at the All-Russian Exhibition in Moscow, and in 1896 at the All-Russian Industrial and Art Exhibition in Nizhny Novgorod, where Sibirtsev was given the first prize in the field for his outstanding study and evaluation of Russian soils and also for the development of a soil classification. In 1897, he took the position of chairman at the Bureau of Soil Science of the Scientific Council of the Ministry of Agriculture and State Properties, replacing V. V. Dokuchayev who became ill. In 1898, Sibirtsev visited Germany, Switzerland, the lowland of Lombardy and Central Italy, and Austria-Hungary, where he studied the soils of Western Europe. At the same time a number of his articles on the classification of soils were published and the first soil map of European Russia, which was compiled on the basis of Dokuchayev's ideas, was issued.

Together with G. I. Tanfil'yev and A. R. Ferkhmin, Sibirtsev compiled a new, more detailed soil map of European Russia according to the plan of Dokuchayev. This map was finished and demonstrated in the Russian Pavillion of the World Exhibition at Paris in 1900.

An especially important role in the development of the modern genetic soil science was played by Sibirtsev's major work, "Soil Science," which consisted of lecture courses given at the Novo-Aleksandriya Institute. He began to work on the course in soil science under the immediate supervision of V. V. Dokuchayev. In 1899, the first edition of the lectures was issued; by 1900 he finished the second edition, which was his last publication.

In the course "Soil Science" Sibirtsev not only vindicated the leading ideas of V. V. Dokuchayev, from which certain pupils of Dokuchayev were deviating, but, by combining these ideas with the teachings of P. A. Kostychev and creatively developing them, advanced the development of

ussian genetic soil science.

Soil, as defined by Sibirtsev, is "a surface, continental, geobiological formation,"² which differs from parent materials both in its composition and the complexity of dynamic processes. Soil, according to Sibirtsev, "is not a closed box, it is the mobile horizon where parent material and outside atmospheric and biological agents interact."³ N.M. Sibirtsev generalized and developed the teachings of V. V. Dokuchayev on soil as a special natural body and the teachings of P. A. Kostychev on soil as a medium of plant growth. In contrast to the opinion prevailing at that time, Sibirtsev understood that the points of view of Dokuchayev and Kostychev did not contradict each other, but, on the contrary, supplemented each other. After having created the first textbook on genetic soil science, which generalized a vast amount of material collected by native and foreign soil scientists, where the points of view of Dokuchayev and Kostychev were combined and developed, Sibirtsev pointed the way to the further development of soil science as a science. N.M. Sibirtsev, in opposition to the prevailing opinions of West European and American scientists, stressed the point that only parent material can form as a result of weathering, and not soil. However, if "biospheric elements take part in the process of the surface modification of parent material, such as plants, animals, and microorganisms, which leave a certain impression on the course and results of weathering and joint products of their life activity and decay (organogenic products) to the parent material, then usual surface horizons form in the Earth's crust, which are called soils..." "... soils belong to the weathering of parent material as the upper, surface horizons of the latter, modified by the additional influence of complexes of organisms." Thus Sibirtsev underlines the leading role of the biological factor in the formation of soil.

No less clearly does Sibirtsev define the lower surface of soils: the sub-soil horizon differs from the soil proper in that it is not modified (at least visibly) by biological agents."

Articles and chapters of "Soil Science" which are devoted to the classification of soils, their properties and development, had a great influence on the development of soil science.

In his articles and in "Soil Science" Sibirtsev also considers problems of the genetic relationship between individual soil groups. Let us remember that as early as in 1882, in the article "The problem of the Siberian chernozem," Dokuchayev wrote: "in the great majority of cases, the Siberian chernozem has an obvious genetic relation to doubtlessly bog soils, solonchek soils and lake soils..." Dokuchayev recognized that "... marine banks and bog areas (Nezhin) imperceptibly merge with neighboring soils and over time (naturally only in places) become covered with or even change into chernozem

themselves."⁴

N.M. Sibirtsev, in developing these ideas of Dokuchayev, comes closer to the modern teaching of a single soil-forming process. "Soils," writes Sibirtsev, "may pass through various phases and forms of development... For instance, certain soloncheks, gradually losing salt by leaching, change into soils of dry steppes or even into chernozem; alluvial soils, escaping from the sphere of influence of river floods, become close to local zonal groups, soils may become swampy, change under the influence of forests, etc."⁵ Sibirtsev considered the problem of the genetic series of soils.

Examining the problem of the variety of soils, he writes: "... the relative persistence of soil-forming processes, (for instance, from the time a region freed itself from an ice cover or a water basin) changes in climate, the advance of a forest in a prairie, swamping, drying, etc. must, in their turn, reflect on the past and present nature of the soil."⁶

The ideas of V. V. Dokuchayev and N.M. Sibirtsev on the role of the age of a land, on the genetic relation between individual soil groups and zones were developed by V. R. Vil'yams, who created the teaching of a single soil-forming process and showed the genetic relation between individual soil zones and groups.

A great role, of the same importance as "Soil Science," which served as a textbook for entire generations of agronomists, forest scientists, and soil scientists, was played in the development and acceptance of the new genetic soil science by N.M. Sibirtsev's soil map of European Russia, first in the form of a small-scale generalized map, and then in the form of a detailed map. The latter was compiled, according to the plan of Dokuchayev, together with G. I. Tanfil'yev and A. R. Ferkhmin. The textbook "Soil Science" and the soil map of European Russia strengthened the position of the young science and made it possible to prepare new cadres of genetic soil scientists, and also to apply the achievements of soil science to agriculture.

* * *

One-hundred years have passed since the birth of N.M. Sibirtsev and sixty years since his death. The theory of the new genetic soil science is closely related to practical agriculture, serving from the very beginning, from the moment of inception, the needs of the people. It proved to be true to life and conquered world opinion. Genetic soil science, created by three Russian scientists, V. V. Dokuchayev, P. A. Kostychev and N.M. Sibirtsev, and developed by V. R. Vil'yams, successfully continues to develop in our times and serves the socialist

⁴ Dokuchayev, V. V. 1882. Trudy V. E. O. 2(3): 17-22. St. Petersburg.

⁵ Sibirtsev, N. M. 1953. Collected works. Vol. 2, p. 314.

⁶ Sibirtsev, N. M. Ibid. Vol. 2, p. 308.

Sibirtsev, N. M. 1953. Collected works. Vol. 2, 306.

Sibirtsev, N. M. Ibid. p. 139.

agriculture.

The merits of N. M. Sibirtsev in the creation of soil science are exceptionally great. A severe illness and early death interrupted the work of this outstanding and talented teacher.

In celebrating the 100th anniversary of the

birth of Nikolay Mikhaylovich Sibirtsev, the soil scientists of the newer generation proudly and gratefully remember the productive life and activity of one of the first three founders of genetic soil science.

Received Marcy 15, 1960

THE WORK OF N. M. SIBIRTSEV ON THE CLASSIFICATION AND MAPPING OF SOILS

YU. A. LIVEROVSKIY

During the short historical period, at the facet of several sciences — geology, physics, chemistry, biology, agronomy — a special branch of natural sciences crystallized — modern soil science. In the course of less than two decades, the new science defined the object of its investigations and their methodological principles, worked out original methods of study and outlined its practical problems.

The rapid acceptance of genetic soil science was possible because of the number of outstanding students and followers of V. V. Dokuchayev. Their creative cooperation with Dokuchayev, their limitless loyalty to leading evolutionary ideas in natural sciences, their relentless activity in the field of practical soil science, and finally, their effective propagation of the achievements of the new science, secured its wide recognition at home and in the whole world.

Among the immediate students of Dokuchayev, a special place is occupied by Nikolay Mikhaylovich Sibirtsev.

N. M. Sibirtsev had a special inherent ability for deep scientific analysis and the know-how to lead to its logical end even a most complicated scientific idea, always remaining within accurate, factual data. This is why in the works of N. M. Sibirtsev one always feels the richness of factual material, the depth of analysis, and accurate formulation, creating scientific investigations of quality.

Precisely these characteristics allowed Sibirtsev to contribute invaluable to the development of the theoretical concepts of genetic soil science, and, in particular, give new elaborate formulations to certain main principles of Dokuchayev.

Among the most important problems to arise before genetic soil science was the necessity of defining the problem of soil classification. Dokuchayev's concept of soil as an individual natural-historical body, forming under the influence of organisms on parent material, required a classification of soil on a completely new basis. While working on the new soil classification, Dokuchayev and Sibirtsev critically analyzed former classifications (that of Fallou, Mayyer, Knop, Teyyer-Schubler, Zenft, Kostychev, and others) and showed errors not only in their

content, but also in their theoretical principles.

In order to imagine the basic, really revolutionary break which Dokuchayev and Sibirtsev made in soil science, it is enough to compare their classification with those existing in Western Europe and Russia. Even the best classifications, which Sibirtsev called "mixed," i. e., trying to unify different principles of soil characterization, were very far from a correct genetic foundation.

In this respect it is interesting to examine the classification of Kostychev, which was popular at that time, and in which the following soil units were distinguished: "1. Muddy soils. 2. Quartz or silicate soils. 3. Clayey soils. 4. Marl, calcareous and dolomitic soils. 5. Humic soils, including: a) bog soils, b) heather soils, c) chernozem soils. 6. Ferruginous soils. 7. Sulfate soils," etc.

The principal taxonomic unit in the first classification, developed by Dokuchayev in 1886, was the genetic soil group, a category which was totally unknown to all former classifications. In analyzing the contents of this early classification of Dokuchayev, Sibirtsev noted "...the importance and fruitfulness of the principles layed down as its basis." He also noted that "...the point of origin of this system are types and forms of soil formation in the sense of a definite combination of soil-forming elements, both material and dynamic" (9, p. 274). At the same time Sibirtsev showed a series of shortcomings in this classification, relating, first of all, to the lack of clarity of the principle of the division of soils into classes according to their location ("normal," "transitional," and "abnormal"). Sibirtsev thought that the terms "normal" and "abnormal" proper were unsatisfactory when related to natural bodies. Sibirtsev also thought that the characterization of the main properties of soil groups, or, according to his terminology "the internal, physico-chemical nature of soils" is not fully motivated by Dokuchayev. The fairness of the criticism was probably recognized by Dokuchayev himself, who in his later classifications took the remarks into consideration (2). At the same time, Sibirtsev was also working on the problems of classification, and published in 1895 his genetic classification which was elaborated later in the versions of 1898 and 1900. The first version of Sibirtsev's classification was based on Dokuchayev's ideas on classification,

which were greatly changed and supplemented. Sibirtsev's classification of 1895 and that of Dokuchayev of 1896 are very close in basic principles. This is also true of later classifications of Dokuchayev and that published by Sibirtsev in 1900 (8). Thus the genetic soil classification was created under the joint efforts of Dokuchayev and Sibirtsev. The closeness of these two scientists as far as problems of soil science were concerned was such that Sibirtsev, taking Dokuchayev's principles as a basis for his classification, developed them further and deeper than his teacher. One of such important classification problems is, for instance, the idea of Sibirtsev on "Zonal, intrazonal and azonal soils," which follows directly from Dokuchayev's considerations, but was not proved by him.

Under the influence of Sibirtsev, Dokuchayev gave a completely new content to his concept of soil "classes." Retaining in his classification the terms "normal," "transitional," and "abnormal" for classes, he made them synonymous with "zonal," "intrazonal," and "azonal."

What were the ideas of Sibirtsev about the zonality of soils?

In zonal soils ectodynamic and special biological phenomena become interrelated during the process of soil formation, according to basic, or typical, conditions of continental zones.

Intrazonal soils, which occur as spots in zonal soil regions, form as a result of the dominance of any single and local "soil-forming agent" over the general zonal factors (for instance, the predominant role of the parent material, additional moisture, etc.).

Azonal, or incomplete soils, are intermediate between soils proper and the parent material. These are undeveloped, coarse skeletal soils, in the formation of which, according to Sibirtsev "...the fine earth-humus portion is subdued or displaced by the unchanging parent material."

The ideas of Sibirtsev on zonal, intrazonal, and azonal soils are firmly established in science, aiding in the development of theoretical concepts of soil science. However, they proved to be insufficiently motivated. This is why Vysotskiy (3, 4), immediately after Sibirtsev, devoted considerable attention in his works to the problem of the zonality and intrazonality of soils. He introduced an essentially new understanding to the terms "zonality" and "intrazonality" of soils. According to Vysotskiy the intrazonality of soils is related to phenomena which he called "oroclimatic." "Zonal" soils develop in more or less flat country on parent material of a medium moisture capacity (clay loam). Such conditions are called by him "flat-land." In contrast to flat-land conditions, he noted other conditions in other parts of the orographic profile, in upland hollows with a more or less deep ground-water table, in the lower portions of slopes with ground water near the surface, etc. In these situations, which are more humid or dryer, "intrazonal" soils develop, corresponding to greater or less moisture as compared with the moisture typical for the flat-land soils of the zone.

The considerations of Sibirtsev and Vysotskiy on zonal and intrazonal soils were widely accepted and are used by soil scientists in practical work. They are related to the contemporary concept of a soil zone as an area with soils of the "zonal" type accompanied by "intrazonal" soils. However, the concept of "intrazonality" needs further development. Of course, a division of soils into zonal and intrazonal has only a relative importance. Ensuing from the teachings of Dokuchayev on soil as a natural body developing in mutual relation with soil-forming factors, all soils must be considered as zonal. The idea of Sibirtsev of "azonal" soils as of "foreign" origin in the geographical landscape, is altogether wrong and should be excluded from soil science. But the understanding of the nature of "intrazonal" soils must be changed, in our opinion. In the majority of cases intrazonal soils develop under the influence on the soil mass of ground, surface, or flood waters, whereby hydrogenic accumulation processes invariably take place. At the same time, the hydromorphous soils of relief depressions, terrace slopes and flood plains are always genetically related to the soils of watersheds by a single cycle of migration of matter. The latter has its own zonal characteristics. This is why intrazonal soils are not an accidental component of the soils.

Thus, a soil zone must be defined in a new way: as an area with a definite type of soil combinations, including zonal soils of flat lands, as well as intrazonal soils developing under hydrogenic or xerogenic conditions. Ecologically different plant groups, forming the basis of the natural vegetation of the zone, correspond to these soil combinations.

The principal taxonomic unit of the classification of Dokuchayev and Sibirtsev, as was mentioned earlier, was the genetic soil group. According to Sibirtsev: "A group of natural soil always corresponds to a definite combination of soil-forming agents." This is why Sibirtsev thought that "...all the varieties of natural soils could be reduced to a certain, more or less limited, number of fundamental soil groups (9, p. 301). Such a point of view prevailed in soil science for a long time. Glinka was the first to have a new understanding of this problem. He distinguished "...five major types of soil formation, or five different methods of soil formation" (1). A given number of soil groups corresponded to each of these ways of soil formation. Glinka's views became the basis for further classification schemes.

The modern concept of soil "group" was formulated by L.I. Prasolov and elaborated by I.P. Gerasimov. Even though it does not fully correspond to the concepts of Dokuchayev and Sibirtsev, it is the further development of the principles of these two scientists. In his classification Sibirtsev does not distinguish between groups of smaller taxonomic units, even though he substantiated in detail the possibility and necessity of detailed subdivisions. "Genetic soil groups, he wrote, are large categories within which many subgroups, types, subtypes, and whole series of genetic soils exist" (8, p. 314).

In his various works, Sibirtsev examined many times the causes determining the genesis of small taxonomic units of soil classification. In

a general way he substantiated the necessity of a "fractional" classification of soils according to the following two criteria: 1) phases of development, or as he put it "according to the nature and degree of the processes which lend to the soil the general features of a given genetic group" (8, p. 313); Sibirtsev gives as an example of this the transitions of soils according to the degree of podzolization "...from sod soils, almost lacking a podzolic horizon, to sharp, bare podzols." 2) "...changes in material factors of soil formation, i.e., variations in the composition and structure of soils as related to the composition and structure of their parent material."

The general principles for dividing soil groups were actually used by Sibirtsev when compiling soil maps. The taxonomic importance of such divisions, for instance the division of soil according to texture, was not fully developed by him, even though it was mentioned in the classification.

In looking over the history of the problem of the introduction of a lower taxonomic category of classification, one cannot but remember the work of Rispolozhenskiy, the soil scientist from Kazan', who was the first (6) to attempt a division of soil groups into smaller classification units: species and genus. He distinguished "genus" by the texture of the soil-forming parent material. The category genus was later fully forgotten by soil scientists and was re-introduced into the classification 50 years later.

N. M. Sibirtsev used classification schemes in the construction of soil maps. As rightfully noted by one of the outstanding students of Dokuchayev, F. Yu. Levinson-Lessing, the first map based on the principles of the scientific classification of soils was the systematic map of the Chernozem Belt of European Russia on a scale of 1:420,000, compiled by Dokuchayev and included in his monograph "Russian chernozem," published in 1883.

The next phase of soil mapping began with the famous investigations of Dokuchayev in Nizhniy Novgorod, in which N. M. Sibirtsev took a great part. By the way, in addition to soil investigations in Nizhniy Novgorod, which lasted from 1882-1887, special studies were made on other components of the geographical landscape. Thus, investigations in Nizhniy Novgorod were the first in the history of the science which were conducted in a comprehensive manner.

In the course of investigations in Nizhniy Novgorod, N. M. Sibirtsev compiled a series of maps, part of which was published while the other part remained in the form of manuscripts, including: 1) Soil maps of the Saratov and Arzamas districts on a scale of 1:420,000 and 2) Soil maps of the Makar'yevo, Knyagin, Vasil'yev, Semenov and Ardatov districts.

In addition to the series of maps for Nizhniy Novgorod, N. M. Sibirtsev compiled many other soil maps on various scales. Among these are soil maps of Kamennaya Steppe and the Starobel portion of Khar'kov Government on a scale of 1:420,000; maps of the suburbs of Novo-Aleksandriya, the eastern portion of Vladimir Government, the Opoch district of Pskov Oblast', and

others.¹

In a special work (7) Sibirtsev gave a description of Russian soils, the second revision after Kostychev. It includes a systematic soil map of European Russia on a scale of 1:20,000,000. The map shows the great success achieved by genetic soil sciences within the short period after its creation.

Besides dealing with soil mapping, Sibirtsev successfully dealt with geological mapping. He compiled a geological map on a scale of 1:420,000, and an interesting map of "sub-soil" formations, or soil-forming material of Nizhniy Novgorod Government, as well as a map of "diluvial drifts" (Quaternary deposits) in European Russia. At the end of his life, Sibirtsev generalized the results of studies on soil mapping and compiled, together with Ferkhmin and Fanfil'yev, a soil map of European Russia on a scale of 60 verst to the inch.

Thus, the contribution of N. M. Sibirtsev to the development of soil mapping in Russia is very great, especially where detailed cartography is concerned.

Up to that time the sources of native large-scale cartography were not mentioned in the literature. As is known, detailed soil maps had been compiled in Western Europe before Dokuchayev made his investigations. However, detailed soil maps, based on the scientific principles of genetic soil science, appeared first in Russia.

While compiling his 10-verst soil maps (1:420,000) of Pskov Government, N. M. Sibirtsev concluded that it was impossible to show on small-scale soil maps the existing diversity of soil, which is of such importance from the point of view of agricultural production. This is why he proposed to supplement small-scale mapping of soils with soil surveys of individual typical areas on a larger scale. Such maps of "key" areas (on a scale of 100 sazhen to the inch) were used as a supplement to his "Soils in the basin of the lower stretches of the Velikaya River" (1900). Later, the soil survey of Pskov Government was continued by D. V. Vikhman, a collaborator and student of N. M. Sibirtsev, the book of which (1903) contains five such maps.

Thus, N. M. Sibirtsev is the founder of our native large-scale soil mapping, as well as the founder of the widely accepted method of so-called "key" areas. It must be noted, however, that because of the generally low level of agricultural technology, detailed soil investigations were almost never conducted in pre-revolutionary times and detailed soil maps were compiled very rarely (soil maps of individual estates and experimental stations).

Nikolay Mikhaylovich Sibirtsev lived a short life full of creative exploration, scientific and organizational work. His early death at the height of his creative ability interrupted his scientific activity. However, the scientific

¹Complete list of maps, compiled by N. M. Sibirtsev, is given in Pochvovedeniye, 1900, No. 4.

legacy of N. M. Sibirtsev, in which the development of soil classification and cartography play a great role, is a great contribution to Russian and world science.

In his memoirs, Ferkhmin (13) describes N. M. Sibirtsev as a man of rare moral qualities. "If you did not know him," writes Ferkhmin, "he could seem dry and severe, while actually he was very kind and generous."

Another contemporary of Sibirtsev, Ototskiy (12), wrote: "When I remember Sibirtsev, the great image of Doctor Faust rises before me, that of a clever, learned ascetic, devoted without reservation to science, wisely organizing his life, respected by all... and dying alone in a far-away place abroad. A tragical end to a hard life."

Yes, the life of N. M. Sibirtsev was not sweet. But today we do not think of N. M. Sibirtsev as being "Doctor Faust," bending over his retorts in his quiet laboratory where the breath of life did not penetrate. No! Everything that N. M. Sibirtsev did, his wonderful investigations in the field of soil genesis, classification, site quality, and cartography is part of the wealth of Soviet soil science aiding in the solution of the problems of Socialistic agriculture.

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THE ROLE OF N. M. SIBIRTSEV IN THE ESTABLISHMENT OF EXPERIMENTAL FIELDS IN THE NIZHNIY NOVGOROD GOVERNMENT

V. SHUBIN

The Nizhniy Novgorod period is not only the longest period of activity in the life of N. M. Sibirtsev, but also the most important in his development as an outstanding Russian scholarly soil scientist, theoretician and practitioner.

In the spring of 1882, when he was 22 years old, Sibirtsev became a member of V. V. Dokuchayev's expedition and in the following years studied the soils of Nizhniy Novgorod Government. In 1885, at the recommendation of Dokuchayev, he remained in Nizhniy Novgorod in the humble position of supervisor and organizer of the first Russian Zemstvo Museum of Natural History, created on the basis of the collection of soils, minerals, parent materials, plants, etc. of the Dokuchayev expedition.

In 1891, N. M. Sibirtsev, with his usual conscientiousness and responsibility, thoroughly and comprehensively studied the characteristics of droughts, their magnitude and nature, clarifying their causes and substantiating the complex of measures for controlling natural disasters and poor harvests in agriculture.

The merits of N. M. Sibirtsev in the organization of experimental agricultural fields in Nizhniy Novgorod Government are especially great. He was the initiator and propagator of the first nucleus of experimental agronomy in this region.

The gubernatorial council of Nizhniy Novgorod Government presented N. M. Sibirtsev's project of the establishment of experimental fields in Nizhniy Novgorod Government at its 27th alternate meeting. In substantiating his proposal of organizing experimental fields, Sibirtsev stressed the point that "Agriculture in the region is the most important branch of the economical life of the population which, at present, needs special attention."

He stated the fact that "...because of a series of unfavorable conditions and crises, the general level of agriculture in the area has definitely lowered. The causes of this are so varied, its consequences so general and deep, that the complete elimination of the present situation will require the continuous and friendly cooperation of all central, as well as local organizations concerned with the welfare of the people...no matter how complicated and how varied the causes of the present crisis are, it

should not be forgotten that one of the main causes is the unsteady routine type of agriculture, especially where the farmer is concerned, a routine which outlived the time when it more or less fulfilled the needs of the agricultural-economic conditions of the state. This is the reason for the great vulnerability of our farm economy to unfavorable natural influences, such as the poor quality of soils, weather, harmful insects, etc. The practice of recent years has clearly shown that the old customary way is too risky, that our economy should gradually change, and its organization and methods should be improved.

The increasing frequency of crop failures is a serious warning for the future..."

"It may be concluded that in an unusual year the crop failure may not have been so severe if natural calamities had not found our soils and plantings in such an unprepared and helpless condition.

All measures taken in agriculture should be such that: 1. They would more closely fill practical requirements. 2. Their results would reflect on the agricultural practices of the farmers of the region, which are deprived (almost without exception) from a direct contact with the theories and conclusions of agricultural science."

"The present moment, in all its depressing difficulty, has a certain good side to it, since it becomes clear to all that following the old ways would mean going down even more. Something new is needed, and this new thing must find expression at this very place, close to the farmer to serve as an example and source of aid to his undertaking."

N. M. Sibirtsev proposed the establishment of practical experimental fields as one of the ways for improving agricultural techniques. Experimental fields in Nizhniy Novgorod Government were organized on the basis of the following considerations:

1. The Governments are concerned with natural, cultural, and economic conditions. Sibirtsev stresses that "...to us, to our managers of the farms, this diversity, this heterogeneous nature of the Government means that what is good for one farming belt is inapplicable to

another. Even if we wanted to, we cannot and must not use general agricultural methods, recommended by agronomy and practice, in the entire Government. We must test these methods, adapt them to local conditions, meanwhile deciding from tests what is good for one farming belt of the Government, and what for the other."

2. Nizhny Novgorod Government has in addition other advantages "...which make the establishment of experimental fields or stations in it expedient and timely — the success of the Dokuchayev expedition and the economy of individual districts as set up by the district council."

N. M. Sibirtsev emphasized that "...the geographical location of Nizhny Novgorod Government and the heterogeneous nature of its territory and population make the agricultural experiments conducted in it important to other areas beyond its limits... The experimental fields of Nizhny Novgorod Government could have not only a local, but a wider, regional importance. The advantage of confining these experiments to our Government consists in the administrative unity of various localities and, even more so, in that the conduct of scientific and as well as economic investigations would make Nizhny Novgorod stand out among other Governments."

According to Sibirtsev, experimental fields must be of two types: agronomical and farmers'.

The object and task of agronomical experimental fields are to "serve as a direct and close intermediary between the requirements and demands of local agricultural practice, on the one hand, and agronomy, technology and economy, on the other."

N. M. Sibirtsev stresses the point that experimental fields must be as close as possible to the practical needs of agriculture. "Our experimental fields should test not only that which interests us but also fulfill the local needs and what can be achieved."

The individual program for each experimental field must be adapted to the peculiarities of the region in which it is located. "The success of experimental fields requires that they be not over-loaded with a series of complicated problems." As special and complicated methods, he mentioned such as, "Experiments on artificial irrigation by the system of dikes."

In addition to purely problems of agricultural practices, experimental fields may also investigate the importance of a given economical branch and its organization (dairy farming, horse breeding and related fields, horticulture, truck farming, apiculture, etc.). Taking into account the zonality of soil and climatic conditions, as characterized and mapped by the expedition of V. V. Dokuchayev, it is expedient to organize in the Government a series of experimental fields, one in each farming belt. At the beginning, at least two or three experimental fields must be set up.

Investigations of a purely theoretical nature "and, in general, all sorts of investigations and determinations beyond the scope of practical ap-

plication" should not be conducted in the experimental fields.

The plots for the experimental fields should contain the necessary agricultural lands, such as plowed land, hay fields, and also, if necessary, forests, truck gardens, etc. The average size of the plots should be 81 acres, varying from 54-135 acres in individual cases. With the exception of initial expenditures for organization, an experimental field should work on the principle of self-support from the proceeds from plots under usual crops. The experimental fields should be managed by specially invited persons with an agronomical education. It is desirable that a number of farmers, of working age and under, be assigned to work the fields so that they may learn and propagate agricultural knowledge among farmers. It is desirable that each experimental field have a small agronomical library with books on agricultural questions for the people.

Farmers' Experimental Fields. The first (and rather educational) experience on the organization of such fields was gained in Perm and Vyatka Governments. Their objectives were: a) to introduce into the economy certain industrial crops, such as oil-producing and fibrous plants; b) to introduce into the farm economy seeds of improved varieties of grain crops; c) to become acquainted in practice with improved methods of tillage and improved implements; d) to become acquainted with various fertilizers, etc.; and e) to improve farmers' meadows and experiments on grass seeding.

Farmers' experimental fields (or "collective experiments," as it was called later) were meant for farmers to test the improved agricultural methods which were already introduced and proved effective on experimental fields.

In Nizhny Novgorod Government, according to N. M. Sibirtsev "farmers' experimental fields must be established on "community lands" which already exist or are being introduced in many settlements... The conversion of community land, either in its entirety or partially, into an experimental field would give the farmer the opportunity to change over to improved methods of agriculture without radically changing his usual ways."

Thus, the guiding principle of the organization of the first experimental fields in the Government, according to Sibirtsev, was their proper geographical arrangement, taking into account the major soil and climatic zones and natural regions, and the possibility of adapting their working program to the practical needs of the farm economy.

On this question Dokuchayev wrote his book "Our Steppe Before and Now," issued for the benefit of those having suffered from loss of harvest. He introduced basic reorganization of Russian agricultural science and higher agronomical education.

In order that investigations on the natural history of Russian agriculture be strictly scientific it was proposed to establish three natural history institutes (soil, meteorological and biological), as well as a wide network of agricul-

EXPERIMENTAL FIELDS

tural experiment stations in various regions of Russia for the practical application of "...the discoveries of science to life and the development of those means which would be most favorable both for the government and for individual land owners."

Future problems were also put forward which were related to the control of unfavorable climatic conditions and the modification of nature by artificial irrigation, afforestation, etc.

The district council decreed that N. M. Sibirtsev's report of experiment fields be reproduced and sent to the public for comments and additions and that the Board work out this problem in more detail, taking into account the public comments and additions and present it for discussion at the next meeting.

In January 1893, the Board introduced a project for establishing two agronomic experiment fields and several farmers' demonstration fields. The Board proposed to invite a government agronomist in addition to the managers of the experimental fields to supervise and develop the experimental agronomic enterprise. It was decided that a special body — the economic council — be created to coordinate the work of the newly established and existing agronomical institutions.

A sum of 11,000 rubles was assigned by the district council for the organization of experimental and demonstration fields.

In November 1893, a government agronomist, N. M. Tkachenko, was invited by the district council. He proposed a new project for organizing an experimental agronomic network in the Government. The new project contemplated the establishment of not two, but five experimental fields (three in 1894). The district council did not approve the project and decreed that only one experimental field be established, for which it assigned 9300 rubles.

The initiator of experimental agronomy in the Government, N. M. Sibirtsev, did not take part in the establishment of this field, since he left Nizhniy Novgorod in August 1892 to take part in a special expedition for the study of the causes of droughts at the invitation of V. V. Dokuchayev.

The new, liberally oriented "political-social" newspaper and the Nizhniy Novgorod stock market bulletin "Volgar" (No. 265 of November 5, 1892) wrote in the column "Local Chronicle" that "the director of the Zemstvo Natural History Museum, N. M. Sibirtsev, was invited to St. Petersburg to take part together with Professor Dokuchayev in studies on the irrigation and afforestation of the Russian steppe belt. N. A. Bogoslovskiy is appointed as the successor of Sibirtsev." The article further outlined the history of the Museum and its organization and made the following conclusions: "...in its present state the Museum consists of a wealth of material for the study of the region from the soil and geological points of view. Its collection is large and interesting."

The newspaper, however, expressed the regret that the "Museum, strange as it may seem, is little visited by the public..." "Soon the

Museum will organize weekly lectures and this may draw the attention of the society of Nizhniy Novgorod to the Museum, which it greatly deserves."

The first experimental field was open in Nizhniy Novgorod in the Spring of 1894 near the village of Bol'shoye Murashkino in Knyagin county. The experimental field, which was purchased by the district council for 3816 rubles and 45 kopeks, covered an area of 164.7 acres and 300 square sazhen. The soil of the field was a dark gray forest-steppe soil (clay loam, changing from chernozem to northern soil).

The first season of 1894 was preparatory. Dwellings were erected, farm and auxiliary buildings were constructed, a second-order meteorological station was established, and the area was leveled and sown with oat to make it even. In the Autumn of 1894 several simple experiments were made with winter crops. By the Spring of 1895 the scope of the experiments was widened, but the final program was put into effect only in the Spring of 1896.

The organization of the experimental field and its experimental program were worked out by the government agronomist together with the manager of the field.

Experimental fields produced good seed which improved the agricultural farm inventory. Several young farmers were enrolled to study improved agricultural methods at the experimental field.

The further destiny of this first experimental enterprise is interesting. The district board was not able to select a real leader, a man with a deep knowledge who would, like Sibirtsev, fully devote himself to experimental agronomy, so closely associated with the needs of farmers of Nizhniy Novgorod. Within three years the experimental field changed managers four times.

The small area of the field, serving as a base for prolonged and episodic experiments, and the lack of qualified workers did not allow the conduct of investigations on the scale and in the variety that were needed.

The district council of Nizhniy Novgorod, as so well-expressed by the government agronomist V. P. Bene, "...wanted to see in the Murashkino experimental field a 'panacea' from all evils befalling agriculture in the Government." This is why after a series of decrees on the working program and reorganization, the council ordered the field closed in 1900 because of "its little use to local agriculture and the doubtful expediency of continuing costly experiments."

After the brilliant investigations of Dokuchayev's expedition, which made Nizhniy Novgorod council famous for its leadership and progressiveness, the discontinuation of the experimental field and the poor state of the Natural History Museum, put Nizhniy Novgorod in one of the last places as far as the development of experimental agronomic institutions was concerned.

"If we had not one experimental field in each county, but 1000 inexpensive experimental fields, then our farmers would know what plants need in each individual case" said K. A. Timiryazev, a

strong believer of experimental work in Russia, in his famous lecture, "Science and the farmer," delivered in July, 1905.

Years passed and life, with its logical inevitability, again put the problem of the establishment of experimental fields in the Government on the agenda.

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PODZOLIC-BOG SOILS

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Soils of the podzolic-bog group are pre-dominant in the taiga zone of Komi Republic. They were described and characterized on the basis of materials of soil investigations in the sub-zone of gleyed-podzolic soils (the sub-zone of the northern taiga) in the Udor district of the Komi ASSR.

Podzolic-bog soils form in flat areas, where there is excessive moisture, primarily because of the accumulation of atmospheric precipitation as a result of the lack of, or slow, drainage. These soils are characterized by the accumulation of peaty, organic substances in the form of poorly decayed forest litter 10-30 cm thick, and also by the gleyization of most of the soil profile. Two types of podzolic-bog soils on clay loam deposits are distinguished according to the intensity of the soil-forming process: peaty podzolic gley-like and peat-podzolic gleyed.

Peaty podzolic gley-like soils are 10-20 cm thick and gleyed in the upper portion of the profile. Green mosses predominate at the surface, consisting 25%-45% of haircap moss, while sphagnum mosses form small, widely scattered cushions. Peat podzolic gleyed soils are covered by a layer of forest litter 20-30 cm thick and are gleyed almost throughout the entire profile. Moisture-loving mosses, such as haircap and sphagnum, predominate at the surface.

Peaty podzolic gley-like soils on clay loam parent material form on gentle slopes (2-3°), on the summits of flat, undulating surfaces and in level interfluvies under spruce and mixed birch and spruce forests belonging to the green-moss and haircapmoss groups.

To characterize these soils let us describe the most typical profiles.

Profile 62-R. August 12, 1953; 63°07'N lat., 48°48'E long. Flat summit of a hill. The microrelief consists of hillocks. The hillocks are old tree stumps ranging from 25-40 cm in height and 100-120 cm in diameter covered with moss over 30%-35% of the area. The forest consists of spruce 11-15 m high with occasional birches, stand density of 0.6, an undergrowth of scattered spruces and birches, and an underbrush of mountain ash. The ground cover consists of hynum mosses (about 60%

coverage), *Polytrichum* (about 40%), horsetail, whortleberry, and hillocks of mountain cranberry.

A₀ 0-15 cm. Dark cinnamon-brown semi-decayed litter. More strongly mineralized in the lower portion. Water seeps through.

A₂B_{hgl} 15-32 cm. Coarse clay loam, cinnamon-brown pockets with an abundance of sesquioxide concretions on a dirty-gray, bluish background. Weak platy structure. Roots and rolled pebbles are encountered. The transition to the next horizon is abrupt.

A₂B_{gl} 32-52 cm. Coarse clay loam of a cinnamon-brownish-yellow color with rusty and bluish streaks. Weak nutty structure of a loose consistence. Roots, pebbles. Seepage water. The transition to the next horizon is clear.

B₁ 52-83 cm. Cinnamon-brown clay loam of a coarse nutty structure. A whitish powder on the faces. Tree roots, pebbles, point concretions of sesquioxides. Lenses of sand are encountered. The transition to the next horizon is gradual.

BC from 83 cm down. Reddish cinnamon-brown clay loam with reddish tinge. Dense, sticky. Half-weathered fragments of parent material of a raspberry color are encountered. The depth of the profile is 100 cm.

Profile 54-R. August 10, 1953; 63°10'S lat. and 48°44'E long. Flat valley. The microrelief consists of hillocks. The hillocks are moss-covered, 25-30 cm high and up to 120 cm in diameter occupying 10%-13% of the area. Spruce forest 10-13 m high with single birches; the crown density is 0.3-0.4. The ground cover consists of *Polytrichum* and green mosses with scattered horsetail and whortleberry bushes.

A₀ 0-19 cm. Dark cinnamon-brown semi-decayed litter, damp and loose. In the lower portion a thin, broken strip of well-mineralized organic matter. The transition to the next horizon is abrupt.

A₂B_{hgl} 19-35 cm. Coarse clay loam. Streaks and pockets of a bluish-gray color on a light cinnamon-brown background, thin platy structure of a dense consistence, moist. Point concretions of sesquioxides; roots, pebbles. The

Table 1

Results of particle-size analysis of podzolic-bog soils in percent of absolutely dry soil

Results of particle-size analysis of peat samples											
Profile Number	Horizon	Depth, cm	Losses during preparation for analysis	Particle diameter, mm						Sum of particles < 0.01	Degree of removal or accumulation of particles < 0.001 in % of material
				1.0—0.25	0.25—0.05	0.05—0.01	0.01—0.005	0.005—0.001	< 0.001		
Peaty podzolic gley-like											
62-P	A ₂ B _{hgl}	15—25	1	13	50	16	4	6	10	20	—57
	A ₂ B _{gl}	35—45	1	9	49	19	5	5	12	22	—48
	B ₁	65—75	1	12	53	5	4	5	20	29	—13
	BC	90—100	1	11	48	7	3	7	23	33	0
54-P	A ₂ B _{hgl}	20—30	2	28	30	16	7	5	12	24	—57
	A ₂ B _{gl}	40—50	1	15	33	21	5	9	16	30	—41
	B ₂	75—85	2	28	21	13	3	10	23	36	—19
	BC	130—140	3	12	29	13	6	9	28	43	0
Peat podzolic gleyed											
11-P	A ₂ B _{gl}	30—40	2	6	20	45	3	10	14	27	—47
	B _{gl}	70—80	3	3	16	44	2	8	24	34	—8
	C	130—140	3	25	21	15	1	9	26	36	0
583-P	A ₂ B _{gl}	35—40	2	9	42	24	2	7	14	23	—47
	B _{gl}	65—70	3	11	45	10	4	4	23	31	—12
	C	100—110	3	7	40	11	7	6	26	39	0

transition to the next horizon is abrupt.

A₂B_{gl} 35-55 cm. Coarse clay loam of a pale yellow color with a cinnamon-brown tinge and occasional bluish spots. Weak nutty structure of a dense consistence, slightly damp. Many point concretions of sesquioxides; roots, pebbles. The transition to the next horizon is abrupt.

B₂ 55-92 cm. Cinnamon-brownish clay loam of a nutty structure with ample powdering of a friable consistence; slightly damp. Individual roots, pebbles and boulders. Lenses of gray sand are encountered. The transition to the next horizon is gradual.

BC from 92 cm down. Cinnamon-brownish structureless clay loam, compact and sticky. Boulders and pebbles are encountered. The depth of the profile is 140 cm.

The upper portion of the profile is gleyed (the A₂B_{hgl} horizon and partly the A₂B_{gl} horizon), there is no evidence of gleyization below. This indicates that gleyization in these soils is governed primarily by prolonged surface wetting.

According to their texture (Table 1), they are coarse and medium clay loams in which fractions of fine sand and coarse silt predominate. The degree of removal of the clay fraction in the A₂B_{hgl} horizon reaches 57%.

The reaction of the soil solution (Table 2) varies from acid and weakly acid in the parent material to strongly acid in the peaty horizons, indicating that the source of the acidity of the mineral horizons of the soil is the decomposition product of the litter. The hydrolytic and exchange acidities are high, especially in the litter, where the hydrolytic acidity reaches 68, while the exchange acidity is 14.5 meq. The exchange acidity results from aluminum. In the upper, gleyed horizons of the profile, exchange acidity is characteristically higher than the sum of adsorbed cations, while in the lower horizons the sum of adsorbed cations is higher than exchange acidity. This apparently results from the tendency of iron and aluminum to enter into exchange reactions with the adsorption complex of the soil, replacing some of the exchangeable cations (2).

Humus penetrates deeply into the profile, being at a maximum in the A₂B_{hgl} horizon. The length of the humus profile and weak humification point to the acid nature and great mobility of humic substances.

The mobile forms of iron accumulate in the gleyed portion of the soil profile. As far as mobile forms of phosphorus are concerned, the picture is less clear, even though there is a definite tendency for their amount to increase in the lower portions of the profile at the transition to the parent material. It is characteristic

Table 2
Chemical analysis of podzolic-bog soils for absolutely dry soil

Profile Number	Horizon	Depth, cm	Hygroscopic water	Ignition loss	Humus (Tyurin)	pH		Hydrolytic acidity	Exchangeable acidity (Sokolov)			Sum of exchangerable bases (Kappen)	In mg/100g soil (Kirsanov)		Degree of base saturation K = 1.0			
						in %	in meq/100 g soil		Total	H ⁺	A ⁺⁺⁺		Ca + Mg	Fe ₂ O ₃		P ₂ O ₅		
																	water	salt

62-P	Peaty podzolic gley-like															
	A ₀	0-15	4.03	94.96	—	24.6	3.0	65.5	114.6	12.36	2.60	9.76	10.3	Trace	3	14
	A ₂ B _{hgl}	15-25	1.36	3.45	1.85	5.2	3.9	5.7	10.0	4.98	0.04	4.94	0	15	2	0
	A ₂ B _{gl}	35-45	2.05	1.82	0.60	5.6	4.0	6.0	10.0	1.91	0.04	1.87	0.10	22	8	2
	B ₁	65-75	3.03	2.15	—	5.9	3.9	6.3	11.0	6.37	0.05	6.32	5.56	13	8	47
54-P	BC	90-100	4.13	1.85	—	5.8	3.8	2.5	4.4	1.80	0.07	1.73	13.10	42	27	84
	A ₀	0-19	8.37	94.52	—	4.3	2.9	68.6	120.1	14.52	2.90	11.62	1.10	Trace	20	15
	A ₂ B _{hgl}	20-30	1.35	3.26	1.52	4.6	3.8	6.7	11.8	5.59	0.08	5.51	0	21	Trace	0
	A ₂ B _{gl}	40-50	1.55	2.93	0.61	5.2	4.0	4.1	7.2	3.49	0.03	3.46	0.80	20	3	2
	B ₂	75-85	1.89	2.26	0.02	5.3	3.9	2.7	4.7	1.92	0.04	1.88	8.30	11	26	75
44-P	BC	130-140	2.84	2.87	—	6.5	5.2	0.4	0.7	0.02	0.02	—	18.10	2	24	98
	Peat podzolic gleyed															
	A ₀	0-15	13.56	90.62	—	4.7	3.3	97.7	171.0	33.86	0.81	33.05	—	287	6	—
	A ₀	20-25	9.48	49.98	—	4.4	3.3	6.05	105.8	22.55	0.79	21.76	4.39	275	5	6
	A ₂ B _{gl}	30-40	1.15	1.81	0.54	5.5	3.9	3.9	6.8	3.75	0.06	3.69	2.11	27	6	35
583-P	B _{gl}	70-80	2.49	2.16	0.33	5.5	3.9	3.9	6.8	3.28	0.05	3.23	12.94	6	23	77
	C	130-140	3.27	3.71	—	5.9	4.3	1.2	2.2	0.51	0.05	0.46	14.60	15	33	90
	A ₀	0-19	14.27	95.02	—	4.3	3.4	—	—	14.15	4.29	9.86	21.95	Trace	9	60
	A ₀	19-24	12.43	73.65	—	4.0	3.6	—	—	18.14	1.33	16.81	14.16	207	5	44
	A ₂ B _{gl}	35-40	2.40	1.97	0.64	5.0	4.2	—	—	6.49	0.05	6.43	2.03	47	1	24
	B _{gl}	65-70	3.58	1.93	1.66	5.2	4.1	—	—	4.10	0.03	4.07	12.5	18	6	75
	C	100-110	4.01	1.16	—	5.6	5.2	—	—	0.07	0.03	0.04	22.41	59	21	99

Note: Comma represents decimal point.

Table 3
Analysis of adsorbed cations in podzolic-bog soils

Profile Number	Horizon	Depth, cm	according to Gedroyts			H	Total acidity (Sokolov)	Total base exchange		Illuvial-accum. coef.		Removal or accumulation compared to parent material		Base unsaturation, % (Gedroyts)
			Ca	Mg	Sum Ca + Mg			(Gedroyts)	(Sokolov)	mobile Ca	mobile Mg	exchangeable bases	exchangeable cations	
mg/ 100g soil														
meq/ 100g soil														
Peaty podzolic gley-like														
62-P	A ₂ B ₁ gl	15-25	1,61	0,06	1,67	5,88	4,98	7,55	6,65	-0,759	-0,987	-89	-61	78
	A ₂ B ₂ gl	15-45	2,2	0,07	2,27	5,99	1,91	8,26	4,18	-0,802	-0,983	-85	-69	72
	B ₁	65-75	8,9	1,7	10,60	6,32	6,37	16,92	16,97	-0,187	-0,606	-30	-1	37
	BC	90-100	10,65	4,4	15,05	1,42	1,80	16,47	16,85	0	0	0	0	8
54-P	A ₂ B ₁ gl	20-30	1,23	0,68	1,91	5,35	5,59	7,16	7,50	-0,917	-0,890	-90	-61	75
	A ₂ B ₂ gl	40-50	1,42	1,33	2,75	3,50	3,49	6,65	6,24	-0,906	-0,797	-86	-68	56
	B ₂	75-85	6,27	3,61	9,88	2,27	1,92	12,15	11,80	-0,547	-0,401	-49	-39	17
	BC	130-140	13,4	5,83	19,23	0,09	0,02	19,32	19,25	0	0	0	0	4
Peat podzolic gleyed														
11-P	A ₀	20-25	3,56	0,83	4,39	—	22,55	—	26,94	—	—	-63	+177 ^a	83
	A ₂ B ₂ gl	30-40	1,95	0,16	2,11	4,04	3,75	6,15	5,86	-0,983	-0,959	-86	-58	65
	B ₂ gl	70-80	10,86	2,08	12,94	3,03	3,28	16,03	16,22	+0,029	-0,444	-24	+7	19
	C ₁	130-140	10,8	3,80	14,6	0,37	0,51	14,97	15,11	0	0	0	0	2
583-P	A ₀	19-24	40,75	3,41	44,16	43,9	18,44	58,06	32,3	—	—	-37	+159	76
	A ₂ B ₂ gl	35-40	1,33	0,70	2,03	7,10	6,49	9,13	8,52	-0,920	-0,903	-91	-60	78
	B ₂ gl	65-70	8,32	4,18	12,50	3,60	4,10	16,10	6,60	-0,502	-0,418	-45	-29	23
	C ₁	100-110	15,52	6,79	22,31	0,10	0,07	22,51	22,48	0	0	0	0	5

^a Calcium made by method of total acidity (Sokolov).

Note: Comma represents decimal point.

that the increase in humus content (for instance in the A_2B_{hg1} horizon) causes a sharp decrease in the content of adsorbed cations. This is associated with the nature of organic substances removed from the litter and having an acid nature. A process takes place here which was described by Ponomareva (8) for illuvial-humic soil formation: the acid products of the decomposition of organic matter, in entering into the mineral horizons of the soil, interact with the adsorption complex of the soil and form calcium and magnesium fulvates which migrate with percolating atmospheric precipitation.

The upper portion of the profile (Table 3) to the B_1 horizon is the poorest in cations (Ca and Mg) and, at the same time, the richest in exchangeable aluminum. The adsorption capacity increases uniformly from the upper part of the profile toward the parent material. Hydrogen or exchangeable aluminum predominate in the exchangeable cations in the upper portion, while in the lower part, calcium and magnesium predominate. The removal of exchangeable cations in gleyed horizons approximates 90%, while underneath it removal decreases slightly. Cations are also at a minimum in horizons in which gleyization takes place.

Total chemical analysis (Table 4) indicates that the upper part of the soil profile is comparatively rich in silica. The impoverishment in sesquioxides, especially iron oxide, in the upper portion of the profile is characteristic, while at the same time the mobile forms of iron (Table 2) have a tendency to accumulation in these horizons, which is associated with gleyization during which the mobile forms of iron become mobilized (Verigina, Zavalishin and Maksim'yuk, 1).

A comparison of the results of the total chemical analysis of the soil and of the clay fraction in profile 54-P (Table 4) shows that the clay fraction is poor in silica and rich in sesquioxides. The behavior of sesquioxides and silica in soil differs. The sesquioxide content of soil increases uniformly from the surface toward the parent material. In the clay fraction, sesquioxides have a tendency to accumulate in the B horizon. In comparing the behavior of silica and sesquioxides in the soil and in the clay fraction one may think that two processes are combined in these soils (10): podzolization accompanied by the decomposition of secondary minerals and the removal of the clay fraction without its decomposition.

Of the other acids worth mentioning is the relative increase of magnesium and phosphorus oxide in the clay fraction. The latter, together with aluminum, apparently occur in larger quantities in secondary minerals than do other oxides. Their content in the profile uniformly increases with depth.

The molecular ratio of $SiO_2:R_2O_3$ in the clay fraction indicates that the montmorillonite-vermicellite is characteristic for the mineral portion of the soil complex.

The results of the analysis of the group and fractional composition of humus (Table 5) point to the high mobility of humic substances and

the predominance of fulvic acids over humic acids. Humus is characterized by an insignificant increase in humic acids of the second group in the A_2B_{hg1} horizon and their total absence in the A_2B_{g1} horizon. Humic acid occurs primarily as free forms of iron humate, aluminum humate and in the form of polymeric complexes with fulvic acids associated with relatively stable sesquioxide hydrates.

The fraction forming part of the polymeric complex with the I fraction of humic acids is absent in the fulvic acid group. The fractions contained in the highest amounts are those of free fulvic acids and fulvic acids associated with mobile sesquioxide hydrates of Fe and Al. Fulvic acid fractions predominate in the humus.

Particle-size, chemical, and total chemical analyses of peaty podzolic gley-like soils (Tables 1, 2, 3, 4) indicate an intense process of podzol formation¹ which takes place on the background of the gleyization process embracing the upper portion of the soil profile.

Let us compare our data with data on podzolic-bog soils (Table 6) of the southern taiga sub-zone (Profile 239-G). The eluvial-accumulative coefficients of the two soils are negative. The absolute magnitudes of the coefficients are higher for the soil of the southern taiga sub-zone, indicating that soil-forming processes are more sharply expressed in it. This shows that the process of podzol soil formation is dying out in the peaty podzolic gley-like soils of the northern taiga as compared to that of the southern taiga, a fact that was pointed out by Ivanova (6, 7) and Zaboieva (5) in relation to soils under zonal conditions.

Peat podzolic gleyed soils over clay loam parent material are very common. They are encountered in combination with peaty podzolic gley-like soils or bog soils. They are covered with swamp spruce or mixed spruce-pine forests in which *Polytrichum* and sphagnum mosses predominate. A description of profiles is given below.

Profile 11-P. July 2, 1953. 3.3 km west of Razgort village, 63°29'N lat. and 49°36'E long. Flat part of an interfluvial (170 m above sea level). The microrelief consists of hillocks. The moss hillocks are 10-20 cm high, 70-80 cm in diameter and occupy 50%-60% of the area. Spruce forest with individual birches 12-14 m high, the crown density is 0.5 and the site quality index Va. Mountain ash forms the undergrowth, the ground cover is a mixture of sphagnum and haircap moss, *Polytrichum commune*, horse-tail, cloudberry, green moss on the hillocks with scattered *Polytrichum commune*.

A_0^1 0-17 cm. Cinnamon-brown, semi-decayed litter, loose, with fungal hyphae; seepage water.

A_0^1 17-25 cm. Coffee colored peat; compact, moist. Pale yellow clay loam with a dirty-blue tinge, yellow, compact with fine pores,

¹ Preserving the podzolization term as a broader inclusive development of illimerization.

Table 4

Total chemical analysis of peaty podzolic gley-like soils, in % of ignited sample

Profile No.	Horizon	Depth, cm	Hygroscopic water		SiO ₂	R ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	MnO	P ₂ O ₅	Total	Molecular ratio		
			%	Ignition loss										$\frac{\text{SiO}_2}{\text{R}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3}$	$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3}$
62-P	A ₂ B _{hgl}	15-25	1.03	3.27	83.63	10.41	1.98	8.43	1.01	0.21	Trace	0.10	95.36	15	113	17
	A ₂ B _{gl}	35-45	1.44	2.54	81.46	13.82	4.29	9.53	0.86	0.13	"	0.06	96.33	11	50	14
	B ₁	65-75	1.97	2.81	80.58	16.31	4.92	11.59	1.01	0.15	0.08	0.15	98.28	9	43	12
	BC	90-100	2.47	3.26	78.44	16.90	5.72	11.18	1.01	1.01	0.10	0.17	97.63	9	36	12
	A ₂ B _{hgl}	20-30	1.02	2.63	81.85	12.0	—	—	0.65	1.36	0.08	0.08	96.02	—	—	—
54-P	A ₂ B _{gl}	40-50	1.01	2.37	84.42	13.25	—	—	0.72	0.97	0.06	0.07	99.49	—	—	—
	B ₂	75-85	1.03	2.64	79.77	14.79	—	—	0.80	1.59	0.08	0.10	97.13	—	—	—
	BC	130-140	1.03	3.11	77.28	16.16	—	—	1.03	1.79	0.12	0.13	96.51	—	—	—
	A ₂ B _{hgl}	20-30	1.88	18.56	58.50	34.87	9.12	25.75	0.32	3.51	0.05	0.24	97.49	3.1	17	3.8
	A ₂ B _{gl}	40-50	1.16	12.83	57.09	35.72	10.36	25.35	0.62	3.53	0.07	0.26	97.29	3.0	14	3.8
54-P	B ₂	75-85	2.16	8.18	56.54	35.11	11.32	22.79	1.12	3.81	0.09	0.23	96.90	3.1	13	4.2
	BC	130-140	2.83	7.39	54.75	34.98	11.87	23.11	1.54	4.09	0.07	0.24	95.66	3.0	12	4.0

Note: Comma represents decimal point.

Table 5

Group and fractional composition of humus from peaty podzolic gley-like soils, % of total carbon (by C)

Profile No.	Horizon	Depth, cm	Wax-resin	Soluble in 1.0 N Na ₂ SO ₄	Humic acids			Fulvic acids				Hydrolyzed in 1.0 N H ₂ SO ₄	Insoluble residue	Humic acid			
					Fraction			Fraction						Total	Total	Total	
					I	II	III	Ia	I	II	III						
54-P	A ₂ B _{hgl} A ₂ B _{gl}	20-30 40-50	26.4 Not det'd.	5.4 6.5	4.3 5.8	7.1 0	2.0 4.8	13.4 10.6	13.5 38.2	0 0	41.4 23.5	0.5 1.1	25.4 62.8	0 0	29.4 20.1	100 100	0.52 0.17

Note: Comma represents decimal point.

PODZOLIC-BOG SOILS

Table 6

Eluvial-accumulative coefficient of podzolic-bog soils

Profile No.	Horizon	Depth, cm	Individual eluvial-accumulative coefficient				EAT	EAM
			Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO		
Peaty podzolic gley-like								
62-P	A ₂ B _{hgl}	15—25	—0,676	—0,293	—0,058	+0,970	—0,063	—0,245
	A ₂ B _{gl}	35—45	—0,278	—0,180	—0,181	+0,251	—0,038	—0,172
54-P	B ₁	65—75	—0,172	—0,009	—0,027	+0,460	—0,023	—0,124
	A ₂ B _{hgl}	20—30	—0,281	+0,042	—0,806	—0,197	—0,055	—0,142
Clay frac- tion 239-G ^a	A ₂ B _{gl}	40—50	—0,151	+0,049	—0,614	—0,173	—0,041	—0,091
	B ₂	75—85	—0,077	—0,046	—0,296	—0,098	—0,032	—0,070
	A ₁	14—19	—0,806	—0,151	—0,389	—0,610	—0,075	—0,351
	A ₁	20—25	—0,763	—0,314	—0,141	—0,666	—0,089	—0,417
	A ₂	30—35	—0,677	—0,397	—0,195	—0,609	—0,092	—0,433
	A ₂ B _{gl}	46—51	—0,047	—0,126	—0,225	—0,318	—0,024	—0,112
	B	70—75	—0,064	—0,046	—0,424	—0,215	—0,016	—0,074
	Peat podzolic gley							
11-P	A ₂ B _{gl}	30—40	—0,380	—0,031	+0,292	—0,447	—0,041	—0,204
	B _{gl}	70—80	—0,024	+0,148	+0,232	—0,116	+0,024	+0,120
583-P	A ₂ B _{gl}	35—40	—0,205	—0,235	—0,032	—0,274	—0,058	—0,132
	B _{gl}	65—70	—0,069	—0,177	—0,326	+0,204	—0,056	—0,118
94-3 ^b	A _{2s1}	31—41	—0,319	—0,261	—0,186	—0,389	—0,051	—0,220
	B _{gl}	50—56	—0,005	—0,184	—0,128	+0,012	—0,022	—0,124

^aProfile Graboski, soil is peaty podzolic gley-like. From the work of Rode (9).

^bProfile Zaboyevo, soil is peaty podzolic gley, subzone of northern taiga kray. From the work of Zaboyeva and others (4).

Note: Comma represents decimal point.

hixotropic. Roots, point concretions of R₂O₃. The transition to the next horizon is clear.

B_{gl} 35-94 cm. Clay loam. Darkish yellow with gleyization spots and pockets of a nutty structure, loose, moist. Roots. Boulders and pebbles are encountered. The transition to the next horizon is clear.

BC_{gl} 94-127 cm. Cinnamon-brownish-red clay loam with dirty-blue spots and streaks. Structureless, compact, moist. Lenses of sand are encountered.

C from 127 cm down. Dark cinnamon-brown clay loam. Breaks up into separate angular blocks with glazed faces; compact. Occasional boulders and pebbles. The depth of the profile is 140 cm.

Profile 583-P. July 19, 1958. 2.9 km to the WNW of the mouth of the Svirla River, 53° 40' N lat. and 51° 42' E long. Flat surface of an interfluvial ridge. Moss hillocks cover 5%-30% of the area. Mixed birch and spruce forest (8 spruces to 2 birches) of a density of

0.4, a height of 8-14 m and with an undergrowth of birch and spruce. The ground cover consists of sphagnum with occasional horsetail.

A₀ 0-19 cm. Slightly decomposed, damp litter.

A₀¹ 19-24 cm. Darkish cinnamon-brown semi-decayed sphagnum peat. Compact, damp.

A₂B_{gl} 24-52 cm. Light cinnamon-brown clay loam with a yellowish tinge and pale blue and rust spots; weak nutty structure, damp; occasional roots. Many point concretions of R₂O₃. Occasional rounded pebbles. The transition to the next horizon is gradual.

B_{gl} 52-78 cm. Cinnamon-brown clay loam with rare dirty-blue spots. Blocky, compact, moist. Occasional roots and rounded pebbles. The transition to the next horizon is gradual.

BC from 78 cm down. Cinnamon-brown clay loam, compact, sticky, structureless. Occasional rolled pebbles. The depth of the profile is 113 cm.

Gleyzation embraces almost the entire soil profile (A_2B_{gl} , B_{gl} and BC_{gl}), except for the parent material. Judging by that, it may be stated that the majority of peat podzolic gleyed soils form under the influence (to various degrees) by surface moisture. These soils formed on coarse and medium clay loam (Table 1).

One may judge of the chemical composition of peat podzolic gleyed soil from Table 2, which shows that the peat litter has the highest acidity (pH 4.0-4.6), which decreases with depth.

Hydrolytic and exchange acidities are high, especially in the upper, organogenic horizons. Hydrolytic and exchange acidities decrease sharply at the transition to the mineral horizons and then gradually toward the parent material. Exchange acidity results from aluminum. Humus is extended along the profile, its absolute content in the A_2B_{gl} horizon is lower than in peaty podzolic gley-like soils. Two maxima are noted in the distribution of exchangeable cations: one in the forest litter, because of biological accumulation, and the other in the parent material, which is associated with the presence in this material of colloids which are decomposed to a lesser degree. The minimum of exchangeable cations is found in the A_2B_{gl} horizon (Table 3).

The content of mobile forms of ferric oxide varies along the profile in the following manner. It is very high in the peat horizons (up to 287 mg), decreases sharply at the transition to the mineral horizons and gradually in the parent material as the intensity of gleyzation decreases. Phosphoric acid has a tendency toward biological accumulation in the litter and its content increases in the parent material.

In examining the adsorption complex of the soil one may see that base unsaturation is highest in the litter and in the podzolic horizon. Hydrogen (as determined by the Gedroyts method) and exchangeable acidity (according to Sokolov) are almost equal within one profile. Their absolute values decrease at the transition from the litter to the parent material. The removal of exchangeable bases in the A_2B_{gl} horizon varies from 86%-91%, depending on the material. Calcium predominates in the exchangeable cations.

Total chemical analysis (Table 7) shows the relative accumulation in the upper portion of the profile (A_2B_{gl}) of silica and the removal of sesquioxides. The total chemical composition of the soil and clay points to the double nature of the processes taking place, i.e., there is no pure illimerization and no pure podzolization. Judging from the molecular ratio (3) $SiO_2:R_2O_3$ in clay it is basically beidellite.

Judging from particle-size, chemical and total chemical analyses of peat podzolic gleyed soils of the northern taiga sub-zone, the process of podzolization is well-developed on the background of gleyzation. In examining the variation of eluvial-accumulative coefficients with depth (Table 6), it must be noted that EAT and EAM are negative in the A_2B_{gl} horizon; their relative values correlate with the clay fraction content. The results of the total

analysis and determinations of eluvial-accumulative coefficients are given in Tables 6 and 7 for Profile 94-Z to show the degree of podzolization of peat-podzolic gleyed soils in the northern and far northern taiga sub-zones. In comparing them we may note that the intensity of podzolization in the peat podzolic gleyed soils in the far northern taiga sub-zone has a tendency to die out, which, however, is not as clearly expressed as in peat podzolic gleyed soils of the northern taiga sub-zone as compared to the same soils in the southern taiga.

In comparing peat podzolic gleyed soils with peaty podzolic gley-like soils we may clearly see that differences in the intensity of bog reflect on the morphological structure and chemical composition of soils. These differences are the following:

The humus content in the A_2B_{gl} horizon in peat-podzolic gleyed soils does not exceed 1%, as a rule, while it has a tendency to increase at the transition to the B_{gl} horizon. The maximum humus content in peaty podzolic gley-like soils is found in the podzolic horizon (1.5%-2.0%), while it decreases in the A_2B_{gl} horizon and has no tendency to accumulate, i.e., the humus of these soils is less mobile than in peaty podzolic gleyed soils.

The exchange and hydrolytic acidities in the litter of peat podzolic gleyed soils are higher than in peaty podzolic gley-like soils, while at the transition to the mineral horizon they are lower. Mobile forms of ferric oxide in peat podzolic gleyed soils accumulate in the litter (up to 280 mg/100 g of soil), as a rule, and their content decreases along the profile. In peaty podzolic gley-like soils the maximum of ferric oxide is found in the podzolic gley horizon.

A comparison of EAM and total analyses (Tables 4, 6, 7) shows that the intensity of the process of podzolization in peat podzolic gleyed soils is lower than in peaty podzolic gley-like soils.

Conclusions

1. Peaty podzolic gley-like soils represent the initial bog stage of gleyed-podzolic soils of the northern taiga. Peat podzolic gleyed soils are the next bog stage.
2. The clay loam podzolic-bog soils described form under the influence of atmospheric wetting without the participation of ground water.
3. During the transition from peaty podzolic gley-like soils to peat podzolic gleyed soils the thickness of peat increases and the intensity and depth of gleyzation increase. With respect to chemistry, the humus content decreases, while its mobility increases. Mobile iron accumulates and exchangeable and hydrolytic acidities increase in the litter.
4. During the transition from peaty podzolic gley-like to peat podzolic gleyed soils, the podzolization process weakens even though the gleyization process becomes more intense.

Table 7

Total chemical analysis of peat podzolic gleyed soil on clay loam parent material, % of ignited sample

Profile No.	Horizon	Depth, cm	Hygroscopic water		Ignition loss percent	SiO ₂	R ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	MnO	P ₂ O ₅	Total	Molecular ratio			
			Hygroscopic	water											SiO ₂ /R ₂ O ₃	SiO ₂ /Fe ₂ O ₃	SiO ₂ /Al ₂ O ₃	
11-P	A ₂ B _{gl}	30-40	1,12	2,16	83,07	13,97	3,90	10,07	0,93	0,97	0,10	0,05	99,09	41	57	14		
	B _{gl}	70-80	2,69	2,79	77,77	17,66	5,75	11,91	0,83	1,25	0,08	0,06	97,65	8	36	11		
	C	130-140	2,87	3,08	79,67	16,65	6,03	10,62	0,69	1,68	0,06	0,13	98,88	9	35	13		
583-P	A ₀	0-19	14,41	94,32	48,63	34,09	17,31	16,68	6,37	5,76	2,41	1,89	99,15	3	7	5		
	A ₂ B _{gl}	35-40	1,75	2,87	80,35	14,83	4,67	10,16	1,08	1,01	0,07	0,03	97,38	10	46	13		
	B _{gl}	65-70	2,54	3,95	80,10	16,41	5,51	10,90	0,81	1,67	0,14	0,04	99,17	9	39	12		
583-P Clay fraction	C	100-110	3,13	3,40	75,69	18,09	5,59	12,50	1,12	1,31	0,17	0,07	96,45	8	36	10		
	A ₂ B _{gl}	35-45	5,17	14,96	58,14	34,78	11,57	23,15	0,19	2,68	0,04	0,06	95,89	3,2	13,4	4,2		
	B _{gl}	65-70	6,59	14,80	56,98	36,31	12,53	23,61	0,15	3,27	0,05	0,17	96,93	3,0	12,0	4,1		
	C	100-110	6,12	13,84	58,24	36,23	14,15	21,98	0,19	2,84	0,05	0,10	95,65	3,1	10,9	4,4		
94-3	A ₂ gl	31-41	0,89	2,18	81,56	12,12	3,49	8,63	0,90	0,92	Trace	0,08	96,37	13	62	61		
	B _{gl}	50-56	1,24	2,37	78,70	15,17	4,11	11,26	0,93	1,47	0,08	0,12	99,61	10	52	12		
	C	65-70	1,88	2,62	77,53	16,10	4,96	11,14	1,05	1,43	0,06	0,14	98,18	9	42	12		

Note: Comma represents decimal point.

5. From the zonal point of view, the process of podzolization in podzolic-bog soils tends to diminish from the southern sub-zone of the taiga to the northern and extreme north.

Received October 2, 1959

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EOLIAN MEADOW-STEPPE SOLONETZ COMPLEXES OF THE MIDDLE IRTYSH REGION

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During cartographic soil investigations in the Maysk, Yermakov, Kuybyshev and partially Bayan-Aul' administrative districts of Pavlodar Region, as well as on the left bank of the Novopokrov district of Semipalatinsk Region, we observed unusual meadow-steppe solonetz soil complexes, never described in the literature. A great role in the formation and development of these complexes (in addition to the usual factors) is played by wind, which governs the formation of an unusual microrelief and associated soils. We call such complexes eolian meadow-steppe solonetz, to underline the important role played by the wind in their genesis.

In spite of the fact that the role of wind in the formation of relief and microrelief has been known for a long time and thoroughly studied, very little work has been done to clarify the direct influence of this dynamic factor on the formation of soil. The activity of wind as a factor in soil formation was first examined, as far as we know, by Petrov (5) with the object of explaining the genesis of certain solonetz and chernozem "medallions" of Eastern Siberia. Lebedev (3) describes the formation under the influence of wind of special "hillocky shor solonchak complexes" found in the desert regions of the USSR. In works devoted to eolian sand relief forms references are also encountered to the heterogeneity of the soil of these formations (6, 7). However, the development of the soil complexity in the sand forms of the eolian relief and microrelief is expressed weakly and predominantly on surfaces close to ground water.

Eolian meadow-steppe solonetz complexes are found on the left bank of the Pavlodar and Semipalatinsk Irtysh region, primarily on the low flood-plain terrace of the Irtysh River, where it is composed of stratified old alluvial deposits containing layers of coarse-textured materials. Such complexes are also found in places on similar surfaces in the valleys of steppe rivers, lakes and salt flats in the marginal areas of the Kazakh small-hill plain, adjacent to the Irtysh valley.

The complexes described develop in the dry feather grass-steppe grass and partly artemisia-feather grass-steppe grass belt of desert steppes, which is very important since vegeta-

tion here does not form a continuous cover and does not fully stop deflation and eolian transport during the dry summer-autumn period.

The climate is characterized by high continentality. Mean annual precipitation varies from 200-275 mm, 140-190 mm of which occurs during the warm period. Mean wind velocity reaches 4.3-4.4 m/sec. The average number of days with strong winds (15 m/sec) reaches 26-48 a year, while the number of days with duststorms is 16-21. Westerly winds characteristically predominate throughout the year, whereby westerly and northwesterly winds predominate in spring and summer, and westerly and southwesterly in autumn and winter. In addition to westerly and southwesterly winds, southeasterly winds play a considerable role in winter. All this promotes the rapid drying of the soil horizons after snow melt in spring and after short rains, which moisten the upper soil layer only, in summer.

In the areas where the described solonetz complexes occur, the salinized and weakly saline ground waters are located at depths of 3, 4 and 5 m in old stratified alluvial deposits. These waters belong to the bicarbonate-sulfate-chloride, sodium, and magnesium-sodium groups (Table 1).

In spite of the fact that the ground water is located at a shallow depth, it has little effect on soil formation because of the poor capillary rise capacity of stratified and fine-textured soils. The upper boundary of the capillary fringe in summer is found morphologically at a depth of 100-150 cm.

The parent material consists of heterogeneous old alluvium, primarily coarse clay loam and sandy loam, often underlain by coarser sand and gravel deposits at a depth of 2-3 m. One of the essential characteristics of the parent material, besides its stratification, is the high content of coarse and medium-coarse sand in many layers (Table 3). These are some of the natural conditions of formation of the soil complexes examined, which have the following characteristics.

First of all, these complexes occupy surfaces with a well-expressed, undulating microrelief. The most characteristic elements of the microrelief of complex areas are the unusual, slightly

Table 1

Chemical composition of ground water in meadow-steppe solonetz complexes

Method and date of sampling	Depth, cm	Solid residue	Alkalinity		Cl ⁻	SO ₄ ²⁻	Ca	Mg	Na ⁺ by difference
			Total in HCO ₃ ⁻	from CO ₃ ²⁻					
Profile 262, June 4, 1957	280	6,004	0,508 ^a	None	0,472	2,660	0,089	0,269	1,161
			8,32		13,31	55,41	4,45	22,12	50,47
Profile 17, July 22, 1956	360	2,32	0,230	Not det'd.	0,730	0,420	0,050	0,020	0,670
			0,38		2,06	0,87	0,25	0,16	2,90

^aNumerator = g/liter; denominator = meq.

Note: Comma represents decimal point.

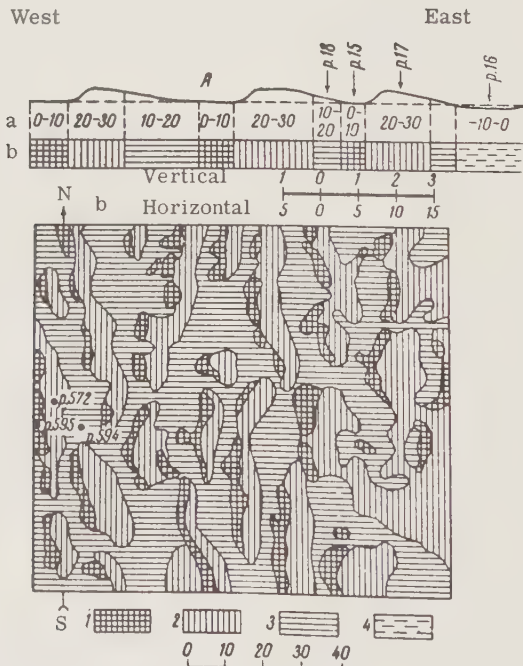


Fig. 1.- Latitudinal profile (A) and horizontal plan (B) of the eolian meadow-steppe solonetz complex (profile near Mayskiy village), horizontal plan near Znamenki village).

a - relative heights of microrelief elements, cm;
 b - soil and vegetation. 1 - fine (crusty), coarse clay loam meadow-steppe solonchak solonetz under *Anabasis salsa* and *Comphorosma* in deflation depressions of the microrelief; 2 - deep solonchak-like meadow-steppe sandy solonetz (with an overblown solonetz horizon) under *Kochia prostrata* and *Artemisia* on wind-deposited microrelief ridges; 3 meadow-like weakly solonetzic chestnut sandy loam and coarse clay loam soils under feather grass, steppe grass and *Artemisia* on medium-high surface; 4 - deeply solonetzic, coarse clay loam chestnut meadow soils under meadow-steppe shrubs in the saucer-like suffosion microrelief.

EOLIAN MEADOW-STEPPE SOLONETZ COMPLEXES

ending ridges or small banks and adjoining depressions on their western side. The small ridges are elongated in a meridional direction, dependent of general relief conditions (slope and the direction of river valleys), which is one of the most important proofs of their formation under the influence of eolian processes, especially if the predominant wind direction is taken into account. The ridges average 7-10 m in width, varying from 3-15 m and more. Their relative height above the mean surface level is most frequently 10-20 cm (and up to 30 cm) and 20-30 cm (and up to 40 cm) above the level of depressed relief. Eastern slopes are characteristically less steep, longer and somewhat more convex, while the western slopes are steeper but shorter, and often slightly concave.

The second microrelief element consists of flat-bottomed depressions, elongated along the eastern slopes of the ridges and having a pronounced outline in the horizontal. The third important element of the microrelief consists of medium-high surfaces, elongated along the eastern slopes of the ridges, and having a poorly-defined eastern slope. They are intermediate between the ridges and the well-defined depressions. Medium-high surfaces include small, poorly defined saucer-like microrelief depressions, apparently resulting from suffosion, which, however, are not necessary components of the microrelief of the complexes studied. The following illustration (Fig. 1) gives a clearer picture of the microrelief described.

It is very essential that the lithological composition of the surface layers of the above-described microrelief elements strongly confirms their formation under the influence of westerly winds. The surface of well-defined depressions, which are deflation depressions, consists of rather fine earths, coarse clay loams, sometimes containing larger stones (3-5 mm) at the surface. The upper, overblown horizon of the ridges (20 cm and more thick) consists of loose sand with an insignificant amount of silt and clay particles and a large amount of medium-coarse and coarse sand. The size of the sand particles in the upper horizon of the ridges characteristically decreases toward the east. The upper horizon of medium-high surfaces usually consists of sandy loam (on the ridges) and coarse clay loam in the portions adjoining deflation depressions. The upper horizons of microrelief suffosion saucers usually consist of coarse clay loam.

The vegetation of the complexes described is spotty, but fairly constant in both dry and desert steppes, which can be explained by a certain influence of ground waters. The vegetation consists of:

a) predominantly camphor, occasional *Ana-sis Salsa*, and rare lomkokolosnik and sedge in well-defined deflation depressions. Vegetation is very scant and covers 10%-15% of the area. Grass height is 5-10 cm;

b) fringed and marine sagebrush predominate on wind-deposited ridges; there is less wormwood-krasnobyl'nik and *Kochia prostrata*. Siberian couch-grass is encountered in places. Ant-fir ephedra, sheep's fescue, sedge, as

well as light-green lichens and brown algae are rare. Sod is characteristically more extensive and the herbage is higher on the eastern side than on the western side of the ridges. Vegetation covers 20%-30% of the surface. Grass height is 20-30 cm.

c) sheep's fescue, hairy feather grass with a conspicuous amount of Austrian wormwood and steppe sedge, small amounts of Siberian couch-grass, wormwood-krasnobyl'nik and sea sagebrush, occasional yellow bedstraw, *Kochia prostrata*, etc., form the vegetative background of medium-high surfaces. Vegetation covers 40%-60% of the area. Grass height is 30-50 cm.

d) in addition to a dense cover of hairy feather-grass and sheep's fescue, large amounts of *Hypericum*-leaf *Spirea*, as well as *koeleria*, and Austrian wormwood, form the vegetation of suffosion saucers. Wormwood-krasnobyl'nik, steppe sedge, *Phlomis tuberosa*, *Gallium verum*, brome grass, purple *Verbascum*, Siberian *Aneurolepidium angustum*, etc., are found more rarely. Vegetation covers 60%-80% of the surface. Grass height is 40-60 cm.

At the present time vegetation promotes, if not the progressive development of eolian microrelief, at least its conservation. The predominant westerly winds remove from the surface of well-defined depressions, which are almost lacking vegetation, all loose and medium-size particles during the dry warm period. The fine clay and silt particles are carried away, while the larger sand particles are transported in an easterly direction where they are caught on ridges covered with vegetation. Deflation leaves only small pebbles at the surface of depressions. It is very probable that a certain portion of loose particles is also removed from medium-high surfaces, from marginal areas adjoining deflation depressions, and deposited in areas adjoining the ridges.

Soil is as varied as vegetation (Fig. 1). Shallow (crusty) meadow-steppe solonchak solonetztes form in well-defined deflation depressions, while deep meadow-steppe solonchak solonetz with an overblown upper horizon form on wind-deposited ridges. Unusual solonetzic meadow-like chestnut soils are found on medium-high surfaces. The latter occupy, at the present time, an intermediate position between automorph (dark-chestnut or light-chestnut) and polyhydromorph (meadow-chestnut) soils, judging by their moisture characteristics. They are usually found where the ground-water table is not very deep (5-6 m) in homogeneous clay loam material. The meadow-like chestnut soils of the Central Irtysh region and neighboring areas of the Kazakhstan small-hill plain form where weakly mineralized or fresh ground water is found at shallow depth (3.5-4 m from the surface). The ground water, however, has little or no effect at all on soil formation. This is because the soil lies on stratified, predominantly coarse-textured deposits, and is often underlain by coarse sandy-gravelly alluvium which interferes with the capillary recharge of soil horizons with moisture from ground water. Meadow-like chestnut soils are widely distributed within the above-mentioned regions. They may not differ greatly from nearby zonal soils as far as their morphological and chemical

properties and vegetation are concerned. Finally, deeply solonetzic meadow-chestnut soils form usually in microrelief suffosion saucers. The quantitative relationships between the components of the complexes, as far as the area they occupy is concerned, vary greatly; both solonetz as well as meadow-like chestnut soils may predominate. However, deep solonetz always occupy a larger area than do the shallow solonetz.

Certain morphological indices (Table 2) and the results of certain analyses (Tables 3, 4) are given below to characterize the soils forming eolian meadow-steppe solonetz complexes.

In examining the table, one must keep in mind that Profiles 15, 16, 17 and 18 are located 4.5 km to the SW of Mayskoye village (Mayskiy district of Pavlodar Region) on a low flood-plain terrace of the Irtysh River; Profile 57 is located in similar conditions but a little farther from Mayskoye; and Profiles 594, 595, 672 are located 19 km to the SW of Znamenki village (Novo-Pokrov district of Semipalatinsk Region) on a low flood-plain terrace of the Chagana River, a left tributary of the Irtysh.

The results of the particle-size analysis confirm that the parent and underlying materials of soils forming the complexes described are heterogeneous (stratified) old alluvial deposits with predominantly sandy loam and coarse clay loam interlayers, enriched with coarse and medium-coarse sand fractions. The high sand particle content of the upper solonetz horizon of the deep solonetz is worth noting. This is attributable to the accumulation of these particles in the process of their eolian transport. The same is true to a lesser extent of the surface horizon of meadow-like chestnut soils. The enrichment of this horizon with sand particles is apparently governed both by processes of eolian accumulation and deflation. Finally, data on the particle-size composition of shallow (crusty) solonetz fully agree with the explanation of microrelief depressions as a result of deflation.

Deep soil profiles, analyzed in Table 3, as well as a series of other profiles described allow the conclusion that the location of solonetz

has no regular relation to the characteristics of the underlying material. Meadow-like chestnut soils, as well as solonetz, may occur on subsoil with varying combinations of fine- and coarse-textured interlayers. It follows that the formation and development of solonetz is not associated with the initial properties of the parent material, but have other causes, such as microrelief, vegetation, and also the historical development of the surface of complex areas and ground water.

Studies on the characteristics of the distribution of the solonetz horizon in trenches cut across the ridges having deep solonetz ranging from shallow solonetz to solonetzic meadow-like chestnut soil (in Profiles 15, 17) have shown that the solonetz horizon is least thick, shallow solonetz has the lowest hypsometric level, and deep solonetz has the highest hypsometric level and the greatest thickness. At the transition from deep solonetz to meadow-like chestnut soil, the solonetz horizon gradually loses its properties and is replaced by solonetzic soil lying at a somewhat lower hypsometric level.

All this, together with what was said previously about the properties of the complexes described, allows the following conclusions to be made on their genesis. In the past, the described surfaces had passed through the meadow-solonchak stage. Later, as the ground-water table lowered, solonchak was replaced by solonetz, which occupied almost the entire surface (with the exception, perhaps, of microrelief depressions which later changed into suffosion saucers). Scant vegetation, and the structureless and dispersiveness of the upper solonetz horizon, especially associated with its specific particle-size composition, promoted eolian processes, as a result of which the initial eolian microrelief developed in the form of small wind-deposited ridges and deflation depressions parallel to them. As conditions for plant growth improved, vegetation became more dense and varied on the solonetz with an overblown horizon thus formed, and partly strengthened the eolian microrelief. Later, as the climate became more generally humid, vegetation on solonetz with an overblown horizon became even more varied and dense. It not only stabilized the surface, but, by retaining the snow

Table 2

Major morphological indices of component soils of the eolian meadow-steppe complex, cm

Soil	Thickness of the horizon		Depth of effervescence	Depth of accumulation horizons	
	A	B		carbonates	salts
Shallow solonchak solonetz (crusty)	3—6	15—25	15—25	30—70	c 15—20
Deep solonchak solonetz with an overblown A horizon	15—25	20—25	30—40	40—100	c 30—40
Solonetzic meadow-like chestnut soils	10—16	20—30	25—45	40—100	>100—120
Deeply solonetzic meadow-chestnut soils	18—22	30—50	40—65	70—150	>200—300

Table 3

Particle-size composition of component soils of the eolian meadow-steppe solonetz complex. Analyzed by Yu. N. Zhdanova and A. G. Novikova

Profile Number	Genetic horizon	Depth, cm	In % of absolutely dry soil											
			Hygroscopic moisture	Losses through treatment with HCl	Diameter of fractions, mm									
					<3	3-1	1,0-0,25	0,25-0,05	sum	0,05-0,01	0,01--0,005	0,005--0,001	<0,001	
Shallow (crusty) solonchak solonetz; microrelief deflation depression														
595	A stz-sch	0-5	0,8	1,1	37,9	7,0	26,2	26,4	59,6	18,7	5,0	7,3	9,4	21,7
	B _{sc}	5-15	2,6	3,8	0,7	13,0	23,2	22,8	59,0	7,7	2,5	8,5	22,3	33,3
	C _{sc}	35-45	2,4	15,0	0,2	4,2	24,1	24,9	53,2	14,1	2,9	6,5	23,3	32,7
	C _{sc}	60-70	1,4	11,7	0,9	4,0	28,5	29,2	61,7	12,8	2,4	5,7	17,4	25,5
	C _{sc}	110-120	1,2	9,7	0,9	16,0	36,3	27,6	79,9	4,7	2,0	2,2	11,2	15,4
57	A stz-sch	0-3	0,4	1,0	1,3	5,5	20,6	36,6	62,7	15,1	9,3	9,6	3,3	22,2
	B _{sc}	5-15	4,6	7,9	None	3,4	12,1	39,9	55,4	13,0	5,6	12,3	13,7	31,6
	C _{sc}	20-30	2,8	13,9	"	1,4	15,1	43,5	60,0	6,9	3,5	12,6	17,0	33,1
	C _{sc}	55-65	3,0	16,2	0,2	1,2	12,2	35,5	48,9	8,8	5,8	18,3	18,2	42,3
	C _{sc}	105-115	2,0	8,7	3,4	7,7	22,4	43,7	73,8	3,5	1,6	1,8	19,3	22,7
	C	190-200	Not det'd.	None	0,8	7,1	72,4	17,2	96,7	0,9	None	None	None	2,4
	Deep solonchak solonetz; microrelief ridge													
17	A	0-7	1,4	0,8	0,8	17,4	32,6	39,2	89,2	5,9	2,4	0,4	2,1	4,9
	A stz	7-17	1,6	0,7	1,0	12,7	29,3	44,7	86,7	5,9	2,2	3,9	1,3	7,4
	B _{stz-sc}	17-29	2,6	2,3	0,3	10,2	19,5	44,2	73,9	10,3	5,7	5,7	4,4	15,8
	B _{sc}	35-45	3,8	11,8	None	5,9	10,6	45,2	61,7	14,9	5,5	11,0	6,9	23,4
	C _{sc}	60-70	2,4	13,3	"	5,2	15,0	47,6	67,8	7,1	3,2	2,9	19,0	25,1
	C _{sc}	90-100	1,8	5,0	2,1	26,1	13,9	46,7	86,7	2,7	1,0	0,8	8,8	10,6
	C _{sc}	115-125	2,4	41,2	3,5	11,7	15,4	45,4	74,9	6,3	2,1	3,2	16,5	24,8
	C	170-180	1,6	18,1	0,4	4,2	12,4	31,1	47,7	17,6	5,7	9,9	19,1	34,7
	C	210-220	3,0	14,4	3,0	13,7	11,5	17,6	42,8	9,3	14,1	8,6	25,2	47,9
	A stz	0-40	2,6	1,0	Not det'd.	"	37,5	41,8	79,3	9,8	4,5	4,5	4,9	10,9
672	B ₁	25-35	2,0	2,8	"	"	22,9	34,4	57,3	9,9	5,0	5,1	22,7	32,8

Note: Comma represents decimal point.

Table 3 (continuation)

Profile Number	Genetic horizon	Depth, cm	In % of absolutely dry soil											
			Hygroscopic moisture	Losses through treatment with HCl	Diameter of fractions, mm									
					<3	3-1	1,0-0,25	0,25-0,05	sum	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
672	B _{stz} -sch	35-45	2,0	4,2	Not det'd.		23,8	33,9	57,7	12,6	3,0	8,0	18,7	29,7
	C _{sc}	50-60	2,0	17,3	"		13,7	33,7	47,4	13,4	6,0	6,6	26,6	39,2
	C _{sc}	90-100	2,8	17,1	"		9,1	12,4	21,5	40,7	3,6	2,3	31,9	37,8
	C _{sc}	115-125	1,2	10,4	"		22,8	44,0	66,8	12,7	0,5	3,2	16,8	20,5
Solonetzic meadow-like chestnut soils; smooth surface of average level														
594	A	0-10	2,2	1,0	1,0	56,5	8,0	14,3	78,8	8,1	2,9	3,7	6,5	13,1
	B _{stz}	20-30	2,2	2,7	0,6	5,0	16,2	26,6	47,8	17,4	4,8	8,9	21,1	34,8
	B _{stz}	35-45	2,0	5,8	1,2	2,0	19,0	22,3	43,3	21,2	5,7	4,9	24,9	35,5
	C _c	60-70	1,8	12,7	7,1	4,0	22,4	30,8	57,2	14,7	4,0	3,5	20,6	28,1
18	A	0-6	2,0	2,7	0,6	8,0	15,9	40,0	63,9	17,0	6,5	7,7	4,9	19,1
	B _{stz}	6-16	2,6	3,1	0,8	7,1	23,2	35,3	65,6	12,4	3,1	10,3	8,6	22,0
	B _{stz}	16-26	3,0	3,7	0,6	8,5	15,0	45,2	68,7	10,8	1,5	9,8	9,2	20,5
	B	30-40	1,6	8,1	0,5	10,8	18,0	47,3	76,1	5,9	1,4	4,9	11,7	18,0
	C	190-200	3,0	20,2	0,6	2,9	8,5	20,6	32,0	17,8	3,4	11,9	34,9	50,2
Deeply solonetzic meadow-chestnut soils; micro-relief of suffosion saucer														
16	A ^{sod}	0-8	2,8	3,3	0,2	6,1	14,8	40,0	60,9	16,8	8,2	9,3	4,8	22,3
	A ₁	10-20	2,2	2,3	2,1	5,6	17,1	36,7	59,4	16,1	6,9	13,3	4,3	24,5
	B _{stz}	25-35	2,0	1,9	0,1	6,4	13,7	32,1	52,5	10,6	10,7	18,4	8,1	37,2
	B _{stz}	50-60	2,4	3,1	None	4,4	12,5	42,4	59,3	9,6	3,9	10,1	17,1	31,1
	C _c	110-120	1,8	15,7	1,0	4,9	21,4	30,5	56,8	11,0	2,6	12,1	17,5	32,2

Note: Analysis and correction for loss from HCl by Kachinskiy's method.

Note: Comma represents decimal point.

EOLIAN MEADOW-STEPPE SOLONETZ COMPLEXES

Table 4

Chemical and physical-chemical properties of component soils of the meadow-steppe eolian solonetz complex

(Analyzed by^a: V. N. Vishnevskaya, M. D. Zubrilina, M. Yesova, I. S. Mezhenina, Z. Sultanbayeva, V. S. Sukhenko, M. B. Varshavskaya, I. I. Yegorova)

Profile Number	Depth, cm	In % of air-dried soil			Water-soluble salts and their components in % of air-dried soil				Exchangeable cations in meq per 100 gm of soil		
		CO ₂ carbonates	Humus	Total nitrogen	solid residue	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na ⁺
Shallow (crusty) solonchak solonetz											
15	0—3	None	1,7	—	0,290	0,021	0,059	0,054	5,0	4,5	0,8
	3—12	"	2,3	—	0,697	0,022	0,321	0,054	5,8	11,5	6,3
	12—21	0,1	1,6	—	1,213	0,027	0,317	0,438	—	—	—
	25—35	3,6	0,7	—	1,209	0,022	0,421	0,285	—	—	—
	70—80	3,2	—	—	0,639	0,030	0,199	0,172	—	—	—
	220—230	—	—	—	0,049	0,021	0,007	0,004	—	—	—
595	0—5	None	2,1	—	0,059	0,007	0,013	0,004	9,4	None	0,1
	5—15	"	1,7	—	—	—	—	—	7,6	13,3	4,2
	35—45	3,4	—	—	1,379	0,017	0,137	0,741	—	—	—
	60—70	3,1	—	—	0,778	0,020	0,143	0,305	—	—	—
	110—120	1,6	—	—	0,908	0,012	0,006	0,610	—	—	—
Deep solonchak solonetz											
17	0—7	—	1,5	0,08	0,030	0,012	0,002	0,004	4,9	0,5	0,7
	7—17	—	1,0	0,06	0,080	0,010	0,018	0,004	—	—	—
	17—27	—	1,6	0,07	0,326	0,031	0,095	0,041	6,6	4,6	5,8
	35—45	2,7	—	—	1,142	0,022	0,195	0,486	—	—	—
	60—70	2,5	—	—	0,581	0,030	0,136	0,208	—	—	—
	90—100	7,5	—	—	0,646	0,020	0,091	0,298	—	—	—
	170—180	7,3	—	—	0,290	0,085	0,045	0,036	—	—	—
	210—220	5,7	—	—	0,189	0,055	0,030	0,036	—	—	—
672	0—10	—	1,1	—	0,037	0,007	0,006	None	7,6	7,6	0,02
	25—35	0,1	1,2	—	0,440	0,037	0,131	0,026	5,7	1,6	4,1
	35—45	0,2	0,7	—	0,852	0,017	0,177	0,349	11,0	12,7	0,6
	50—60	5,1	—	—	0,931	0,022	0,266	0,283	—	—	—
	90—100	5,2	—	—	0,700	0,029	0,266	0,131	—	—	—
Solonetzic meadow-like chestnut soil											
18	0—6	None	3,5	0,17	0,093	0,017	0,018	0,004	19,8	1,3	None
	6—16	"	1,5	0,10	0,044	0,012	0,001	0,004	16,8	4,4	0,5
	16—26	0,5	1,0	0,06	0,091	0,027	0,002	None	15,4	3,8	0,2
	30—40	2,8	0,8	0,04	0,089	0,025	0,002	"	10,6	3,3	None
	190—200	7,3	—	—	0,097	0,029	0,027	0,004	—	—	—
594	0—10	—	2,6	—	—	—	—	—	13,2	6,6	0,5
	20—30	—	1,7	—	—	—	—	—	15,1	7,6	0,4
	35—45	1,2	1,6	—	—	—	—	—	15,1	6,6	0,3
	160—70	4,4	—	—	—	—	—	—	—	—	—
Deeply solonetzic meadow-chestnut soil											
16	0—8	—	5,8	0,29	—	—	—	—	17,2	2,2	0,2
	10—20	—	3,0	0,15	—	—	—	—	12,2	3,5	0,5
	25—35	—	1,9	0,11	—	—	—	—	11,9	3,3	0,7
	50—60	0,1	0,9	0,08	—	—	—	—	13,6	3,2	0,6
	110—120	6,2	—	—	—	—	—	—	—	—	—

^aMethod of analysis: CO₂ — Geysler-Maksimuk; humus—Tyurin; nitrogen—Kjeldahl; water extract—Gedroyts; adsorbed calcium, magnesium—Shmuka; adsorbed sodium—Puri-Grabarov. Note: Comma represents decimal point.

in winter, it accelerated the self-melioration of the solonchaks, both by leaching, as well as by the intensification of biological processes. This was also promoted by good, natural drainage as a result of the highly water-permeable underlying material. Thus solonchak meadow-like chestnut soils gradually formed and increased in area at the expense of shallow and deep solonchaks. At the same time a gradual leveling of the surface occurred under the steppe grasses covering meadow-like chestnut soils. The process of development proceeded thus with time in the direction of a decrease in the total area of solonchaks, especially shallow solonchaks, which shrank in the west as a result of their gradual transition to solonchak meadow-like chestnut soils, and in the east as a result of their gradual filling and transition to solonchaks with an upper overblown horizon, and also as a result of the decrease in the area of deep solonchaks associated with their gradual transformation into solonchak meadow-like chestnut soils. Such tendency in the development of the complexes is retained at the present time, even though the process is very slow for the following reasons. The prevailing westerly winds blow the snow in winter away not only from the vegetation-free depressions, but also from the poorly sodded windward side of the ridges (up to their crest). Snow is partially retained on the better sodded lee side of the ridges, but primarily accumulates on meadow-like chestnut soils, especially meadow-chestnut soils which are well-covered with grasses. During the thaw in spring most of the melt-water is absorbed by the highly water-permeable surface horizons so that almost no redistribution of moisture to the individual microrelief elements occurs by surface runoff. Flooding of microrelief depressions occurs primarily after winters with heavy snow as a result of subsurface runoff along the surface of the solonchak horizon (in deep solonchak) and along the solonchak horizon (in solonchak meadow-like chestnut soils). These waters apparently promote the replenishment of water-soluble salts and the development of shallow solonchaks. At the same time, the degradation of deep solonchaks continues along their boundaries with solonchak meadow-like chestnut soils, where moisture conditions are more favorable for plants (however, it is possible that in a number of cases, when the overblown horizon is sufficiently thick it preserves the solonchak horizon). Summer precipitation does not play an essential role in the process of solonchak formation and leaching of salts, since it moistens the upper horizon only. In summer and autumn deflation processes take place, that is, the removal of solonchak, of fine loose sand and clay particles, which lost their connection with the soil as a result of solonchak formation. The process of deflation also embraces in an insignificant degree the peripheral, eastern portion of meadow-like chestnut soils, adjoining microrelief deflation depressions. Besides, processes of eolian accumulation (wind-deposition) of large sand particles on the surface of deep solonchaks continue, as well as processes of surface leveling of meadow-like chestnut soils. Thus, present conditions promote the decrease of the complexity of soil on the one hand, and aid in the preservation of the unusual eolian microrelief and associated soils.

Conclusions

1. Unusual meadow-steppe solonchak complexes are widely distributed on the left bank of the middle Irtysh River. A great role in their formation and development was played and is still played by the prevailing westerly winds along with other factors.

2. As a result of wind activity in the past, an unusual eolian microrelief formed, which persists to this day. The microrelief consists of small deflation depressions, bordered on the east by wind-deposited microrelief ridges and leveled medium-high surfaces which divide the previously mentioned genetic pairs of microrelief. Wind-deposited microrelief ridges, in the form of slightly winding strips, and deflation depressions, in the form of well-defined chains are always elongated in the meridional direction, independent of the general relief conditions (slope and the direction of river valleys on low flood-plain terraces where these microrelief forms preferentially occur), which proves their eolian formation.

3. The complexes are formed by: a) shallow (crusty) meadow-steppe solonchak solonchaks, developing in microrelief deflation depressions under a scant *Anabasis camphor* vegetation; b) deep meadow-steppe solonchak solonchaks with an overblown sand on solonchak horizon in ridges covered with *Kochia prostrata* and *Artemisia*; and c) solonchak meadow-like chestnut soils occupying leveled medium-high surfaces under *Artemisia*, feather grass, sheep's fescue. In a severe case in the complex the deep meadow-chestnut solonchak are formed in suffusion microrelief saucers under shrubby meadow-steppe vegetation.

4. The areal distribution of the components of the complex described (the soils listed previously) is independent of the nature of the underlying material, which also indicates that the microrelief and associated soils formed under the influence of eolian processes.

5. At the present time, the eolian meadow-steppe complexes are used in agriculture exclusively for low productive pasture. The improvement of the pastures and of the soils in the complexes described would require appropriate measures for the melioration of solonchak and for the control of deflation.

Received March 23, 1959

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SOIL FORMATION PROCESSES AND THE CLASSIFICATION OF FLOOD-PLAIN SOILS IN THE STEPPE ZONE OF THE CENTRAL CHERNOZEM BELT

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The processes of flood-plain soil formation have not been studied enough. This refers especially to the flood-plain soils of the steppe zone, which have almost never been described from the point of view of their genesis and their fertility and suitability for agriculture. Because these soils have been studied so little they cannot be classified, and without a general classification there cannot be agreement on the nomenclature of flood-plain soils. Various terms are used for one and the same soil variety: sod (16, 17, 37, 38, 39), sod-meadow (8, 9), meadow (30), etc., while the various soils are unified under terms, such as stratified, granular-stratified and granular.

Flood-plain soils of the forest zone are described in the literature more often (1, 5, 7, 13, 16, 17, 32, 37) than the flood-plain soils of the forest-steppe and, especially, the steppe zones (2, 27).

A classification of flood-plain soils must be based on the study of the flood plains of both large and small rivers. The areas of small rivers are in many instances larger than those of large rivers. The flood plains of small rivers differ morphologically from those of large rivers in that they are not divided into a bog pre-terrace part, a central granular or granular-stratified part and a stratified portion along the river. As a rule, there is no stratified sand area along the river; the bog pre-terrace area is not always pronounced; and dunes and ridges do not form part of the relief of these flood plains. An important role in the formation of flood plains is played by ravine fans, which often reach in a long tongue into river valleys, form an obstacle to runoff and promote swamping, especially in the flood plains of small rivers.

Different soils form depending on the relief of the flood plains, vegetation, the nature of alluvium and the water regime. The idea of the evolution of flood-plain soils was first formulated by Polynov (30, 31); it was especially clearly developed in a work by Iozefovich (20) in which it is shown that the main direction in the evolution of flood-plain soils is governed by the intensification of zonal conditions and the diminution of hydromorphism, which, in our opinion, is the general principle of the evolution of flood-plain soils. In every soil zone, the parts of a flood plain which are not, or are only slightly, affected by alluvial and flood-plain processes

have soils which resemble zonal soils by their habit and properties. This was noted by many investigators of flood-plain soils.

The development of sod-podzolic soils in the flood plains of the forest zone was mentioned by Afanas'yeva (1), Grabovskaya (13), Vilenskiy (7), Dobrovol'skiy (16), Tyuryukanov (37), Bulgakov (5) and others. The development of chernozem-like soils in the flood plains of the steppe zone was mentioned by Iozefovich (20), Blazhniy and Tyuremnov (2), Voronova (8, 9), and others. The formation of chestnut and brown soils in the arid steppe and semi-steppe zone was described by Plyusnin (28), etc. The concept of the development of flood-plain soils is being more and more widely accepted. Their classification should be based on types of processes or stages of soil formation. One or the other type of soil formation process, corresponding to a given stage of soil development, reflects its set of conditions for soil formation at the given moment and is expressed by a definite soil group. Soils of the same type of formation differ one from the other by the degree in which the process is expressed, which manifests itself in a definite set of morphological soil indices, in the chemical composition and texture of soils, their hydrological and physical properties, etc.

All types of soil formation in flood-plain soils are governed primarily by the water regime and vegetation. The great role played by the water regime in determining the direction of development of one or the other soil group and, in particular, flood-plain soils, is now being recognized by many investigators, among which are Iozefovich (20), Thornthwaite (40), Kovdu (23), Kovdu and Yegorova (24), Tomashevskiy (36), Bulgakova (5), Tyuryukanova (37), Dobrovol'skiy (17), Yegorova (18), and others.

A. A. Rode (33) considers soil water as a very important factor in soil formation; Bulgakov (5) is of the same opinion and notes that the nature of the water regime and the chemical composition of soil water determine the direction the soil-formation process will take and the quality of soils. Tomashevskiy (36) wrote that the water regime, which is governed by surface (river) and ground water, is the main factor of soil formation in a flood plain, since a change in the water regime is accompanied by invariable changes in the bioecological conditions of the medium and establishes a new complex of soil processes.

FLOOD-PLAIN SOILS

The water regime of flood-plain soils consists of flood, ground, and atmospheric water. One or another group of plants develops depending on moisture conditions. The type of soil formation corresponds to the nature of the water regime and the type of vegetation.

As a result of what processes does the formation of flood-plain soils occur? There is no one opinion on the subject in the literature. Vil'yams (6) thinks that the formation of flood-plain soils occurs under the influence of the sod process of soil formation. Prasolov (32) is of the opinion that the formation of flood-plain soils occurs during the sod-meadow stage of soil formation. Plyusnin (29) believes that flood-plain soils form as a result of the meadow-alluvial type of soil formation. Afanas'yeva (1), and Grabovskaya (13) consider that flood-plain soils of the forest zone form as a result of a combination of processes: alluvial and podzolic.

A. A. Tyuryukanov (37) distinguishes three stages of flood-plain soil formation: clay, through which flood-plain soils pass during the flood period, meadow and sod. Dobrovol'skiy (17) distinguishes sod, meadow and bog processes in flood-plain soil formation in the forest zone. Bulgakov (5), and Bogatyrev (3) point to the necessity of taking gleyization processes into account in the formation of flood-plain soils.

Our investigations in the flood plains of the Sukhaya Rossosh', Gnilaya Rossosh' and Balka Popova Rivers (1956-1958), which are located in the steppe zone of the Central Chernozem Belt (CCB), have shown that, in the flood plains of the steppe zone, the following processes of flood-plain soil formation may be distinguished. (Table 1).

1. The subaquatic process of flood-plain soil formation which proceeds under conditions of continuous soil surface flooding and the development of water and bog vegetation including *Phragmites communis* Trin., *Scripus* L., *Typha latifolia* L., *T. angustifolia* L., *Nuphar luteum* (L.) Smith, *Equisetum heleocharis* Ehrh., *Sagittaria* L., and occasional *Polygonum amphibium* L. In areas where the surface water is 10-15 cm or less deep, *Scripus* L. and *Phragmites communis* Trin. are replaced by sedges, most often *Carex vulpina* L., and there are many *Veronica scutellata* L. The main mass of the root system is located at the surface of the bog, while only roots with air ducts, such as those of *Phragmites communis* Trin. and other plants, penetrate into the alluvium. The alluvium is bare of sod in places. Sometimes alder bogs are encountered along the shore with *Alnus glutinosa* (L.) Gaertn., *Populus tremula* L., *Betula pubescens* Ehrh. and an undergrowth of *Rhamnus flangula* L., *Salix cinerea* L., etc.

As a result of the development of this process, clay soils form, the composition and properties of which are directly affected by the surface water layer. First, this layer creates anaerobic conditions in the soil and, second, the substances and microorganisms in it take a direct part in the process of modification and transformation of alluvium, and plant, bacteria and animal remains. As a result of this, these soils are structureless and contain reduced compounds throughout the profile.

2. The bog process of soil formation in flood plains develops under conditions of constant excessive wetting by ground water, which moves by capillarity toward the surface of the soil where it often stagnates during heavy rains and when the ground-water table rises in spring and summer. A typically bog vegetation develops under these conditions, consisting primarily of sedges: *Carex vulpina* L., *C. diandra* Schrank, *C. appropinquata* Schum., *C. elongata* L., *C. caespitosa* L., etc. Altogether sedges constitute 70%-80% of the species, the remaining portion is represented by *Glyceria arundinacea* (M.B.) Kunth., *Iris pseudacorus* L., *Alisma* L., *Bidens* L., *Mentha pulegium* L., *Equisetum* L., *Deshampsia caespitosa* (L.) P.B. and certain other plants. Thickets of *Salix* L. are everywhere. There are many sedge mounds up to 60-70 cm high. The dense sod is up to 18-20 cm thick and consists of coarse, woody sedge roots. Clay-bog, humus-bog, and peat-bog soils, as well as rare peat beds form here.

3. The sod-gley process of soil formation develops under conditions of constant capillary water recharge within the soil and the development of moisture-loving plants, which are represented primarily by tall sedges: *Carex vulgaris* Fr., *C. gracilis* Curt. and *C. elongata* L., constituting 50%-60% of the vegetation of wetter areas; there is a comparatively large amount of *Alopecurus* L. (25%-50%) and sometimes *Sium* L. Vegetation of less wet areas is represented by *Phalaris* L., *Calamagrostis epigeios* (L.) Roth, and mixed herbage. *Equisetum* L., *Rumex acetosa* L., *Poa* L., *Agrostis* L., *Sanguisorba officinalis* L., *Potentilla anserina* L., *Ranunculus scelerotus*, *Inula* L., *Plantago lanceolata* L. and *Plantago tenuiflora* W. et K. are encountered comparatively frequently. Legumes include *Lathyrus pratensis* L., *Vicia cracca* L., and occasional *Trifolium rubens* L. There are many *Salix* L. shrubs.

In areas where the parent material consists of loess-like clay and clay loam, the largest area is occupied by legumes (45%-55%), including *Trifolium rubens* L., *T. repens* L., *Melilotus* L., *Lathyrus pratensis* L., *Lotus corniculatus* L., and *Medicago cancellata* M.B. Sedges (*Carex*) are also encountered here. The amount of grasses is small (20%-30%) and they are represented by *Glyceria arundinacea* (M.B.), *Festuca* L., *Poa trivialis* L. and certain other species. Mixed herbage is represented by *Tussilago* L., *Sium* L., *Symphytum* L., *Sonchus paluster* L., *Cichorium* L., *Sonchus arvensis* L., *Geranium pratense* L., *Achillea* L., and *Cirsium* agans. The sod is continuous and comparatively thick, but consists of roots and rhizomes of herbs, legumes, grasses and sedges. The root system of plants penetrates deeper than that of bog vegetation.

Salt-tolerant plants are also encountered, including *Limonium gmelinii* Wild. Ktze., *Aster tripolium* L., *Scorzonera parviflora* Jacq., and *Juncus Gerardi* Lois. Sod-gley soils develop as a result of this soil formation process. The process of soil formation in which the layer containing the plant roots is moistened by the capillary rise of ground water, is often called, according to Gerasimov (12), by the vague name of "meadow." This term does not clarify the process of soil formation and, to our opinion, should

better be used to indicate the location and not the process and type of soil formation.

The sod process develops to the depth of the capillary fringe in sod-gley soils, as a result of which humus and ash elements accumulate, a granular structure forms, etc. In the zone of capillary saturation and stagnation of ground water iron hydroxide and reduced compounds (products of gley formation) accumulate. Thus, sod and gley processes develop here simultaneously.

4. The sod-meadow process of soil formation takes place under conditions of surface wetting. The capillary wetting has no effect on the formation of the soil profile, since the layers containing plant roots are disconnected from the capillary fringe. The vegetation is mesophytic-xerophytic and represented by grass and mixed herb associations. The grasses include Agropyrum repens (L.) P. B., Bromus secalinus L., Alopecurus L., Festuca L., Poa pratensis L., and Koeleria gracilis Pers. Grasses constitute 50%-70% of the vegetation. The remaining part (25%-50%) is represented by mixed herbage, such as Symphytum officinale L., Ranunculus acer L., Ranunculus repens L., Euphorbia L., Potentilla reptans L., Xanthium spinosum L., Geranium pratense L., Geranium collinum Steph., Carthus L., Lactuca L., Serratula L., Mulgedium tataricum (L.) D. C., Leontodon L., Crepis L., Taraxacum bas-sarabicum (Fisch.) Hand. -Maz. and Juncus gerardi Lois.

In the willow underbrush there are many Cuscuta lupuliformis Krocke, Heracleum L., and Inula L. There are few legumes (3%-8%), represented by Lotus corniculatus L., Vicia cracca L., Astragalus L., Trifolium L., T. rubens, T. repens L., and T. fragiferum L.

The sod in these meadows is not very thick, 5-15 cm, and the soil is covered 70%-90% by herbage. The soil formation process under such moisture conditions is often called the sod process (17, 38), however, in flood plains the sod process does not occur in its pure form, but is interrupted by floods and deposition. The stronger the influence of floods and the larger the volume of the deposits, the less pronounced is the sod process. This is why it is necessary to add the term "meadow" to the term "sod" in the case of flood-plain soils to indicate that the sod process takes place precisely in a flood plain.

5. In sections of flood plains of the steppe zone which are not subjected to alluvial and flood-plain processes, soil formation occurs by the sod-steppe process. These sections are represented by xerophytic vegetation of dry and steppe-like mixed herb and fescue meadows, which clearly reflect the lack of moisture. Grasses (40%-60%) are predominantly represented by Festuca sulcata Hack. and Poa L. Koeleria gracilis Pers., Bromus arvensis L. and Agropyrum repens L. are also encountered.

Legumes consist of Medicago falcata L., Lotus corniculatus L. and Astragalus L. Altogether legumes constitute 5%-15% of the vegetation and mixed herbage, 25%-50%. The herbage is represented by Achillea L., Cheno-

podium L., Linaria Jiss, Artemisia inodora M. B., Artemisia hololeusa M. B., Galium verum L., Plantago media L., Malva L., Cichorium L., Galeopsis L. and others. The herbage is thinned and covers 50%-65% of the ground. Chernozem soils form during the development of the sod-steppe process of soil formation.

Chernozem-meadow and meadow-chernozem soils form in areas where the parent material is represented by loess-like clay loam and clay, which, in flood plains, are encountered in the form of monadnocks and ledges of the first flood-plain terrace. Ground waters participate in the formation of the profile of chernozem-meadow soils, while they are outside the limits of meadow-chernozem. Chernozem-meadow soils develop as a result of the sod-gley soil-formation process, while meadow-chernozem soils result from the sod-steppe process. Each soil group has several sub-groups, depending on the intensity of the soil-formation process, which manifests itself in the nature of the accumulation of organic substances.

Soils which differ in their parent material, in texture, in the humus horizon, and in salinity also differ in their genesis and suitability for agriculture. This is why we subdivided each soil group according to the foregoing, as it can be seen from our classification scheme for flood-plain soils. The peculiarity of soil formation in flood plains lies in that it is affected by floods, annual deposition of mud, and, frequently, ground water. Flood waters create for a certain time anaerobic conditions in all flood-plain soils, leach out salts from the soils (sometimes promote their accumulation), deposit alluvium, and preserve low winter temperatures in flood-plain soils for a longer time than they stay in the soils of watersheds. Soil formation processes slow down during floods, since the temperature of the flood water in the steppe zone varies from 2-7°C (according to data from the meteorological station at the village of Podgornoye) and all chemical, physical and chemical, and biological processes are weakened during this time. All these processes reach maximum intensity when the soil temperature rises above 20°C, that is in July. The conclusions of Tyuryukanov (37) in this respect are entirely wrong. He believes that during the flood period flood-plain soils undergo the clay stage of their development, which is characterized by enhanced biological processes and the deep diagenetic modification of organic and mineral substances in flood-plain soils. During the flood period no enhancement of microbiological processes can occur, since flood waters inundate flood-plain soils that are still frozen and the temperature of the flood water does not exceed 2-7°C.

Organic and mineral substances cannot undergo deep diagenetic modifications during the flood period, because its duration is not sufficient for this. During the flood period, alluvium and the surface layer of flood-plain soils can rather undergo a certain amount of physical and chemical weathering, but the rate of these processes is very low at low temperatures, which was convincingly shown by Jenny (22) on the basis of E. Ramann's data. The effect of annual mud deposits on soil processes varies depending on their thickness. Mud deposits up to 1.0 cm thick

Table 2
Composition and properties of flood-plain soils in the steppe zone as exemplified by the flood plains of the Sukhaya Rossosh', Gnilaya Rossosh' and Balka Popova Rivers

Soil	Humus, %		In % of ignited sample										CO ₂ carbonates, %										Solid residue, %										Thickness of the humus horizon, cm
			Fe ₂ O ₃ ^a					SiO ₂ : Al ₂ O ₃ ^b																									
	C ₂ O					Depth, cm																											
	0-10	20-30	40-50	60-80	90-110	0-10	20-30	40-50	60-80	90-110	0-10	20-30	40-50	60-80	90-110	0-10	20-30	40-50	60-80	90-110													
Clayey	9.52	4.05	3.19	2.76	2.51	10.0	6.6	7.0	6.9	6.2	1.68	2.79	3.03	2.49	5.83	3.12	2.84	2.70	2.60	2.33	1.06	0.38	0.21	0.17	0.25	Not developed							
Clayey-bog	8.83	4.60	3.04	2.38	—	8.42	9.06	10.41	7.62	6.20	8.60	8.21	8.03	6.97	5.03	4.06	3.64	3.48	2.24	1.68	0.52	0.31	0.20	0.25	0.23	Not developed							
Sod-gley	6.46	4.64	3.32	—	—	3.4	(5.5)	(5.5)	(5.3)	(6.5)	7.73	7.03	7.38	6.32	6.21	6.06	3.26	3.20	2.05	2.41	0.31	0.21	0.20	0.20	0.10	31							
Sod-meadow	6.06	5.74	5.00	4.42	3.12	7.34	7.13	7.02	7.01	7.62	5.56	5.64	5.92	6.32	6.20	1.86	1.91	2.28	2.38	—	0.14	0.13	0.12	0.11	0.07	57							
Meadow-chernozem	6.32	5.60	4.85	4.91	0.61	5.91	6.02	5.87	5.51	5.85	4.51	5.62	7.11	10.78	16.51	1.30	1.30	2.05	5.64	4.11	1.00	0.42	0.07	0.08	0.05	0.05	86						
Ordinary chernozem	5.83	5.17	3.83	1.83	0.19	6.93	7.87	7.87	7.01	7.47	3.58	4.51	6.16	11.05	17.41	0.06	0.08	1.50	5.17	7.8	0.44	0.06	0.06	0.08	0.03	101							

aFe₂O₃ — numbers without parentheses.

bNumbers in parentheses — ratio SiO₂:Al₂O₃.

Note: Comma represents decimal point.

have almost no effect on soil development, while thicker deposits, especially those 5, 10, and 15 cm thick, disturb the course of the soil-formation process and in this case annual mud layers differ from each other and form stratified deposits. This is especially pronounced in the sod process. In areas where mud deposits are thick, the humus horizon is very weak, the structure is poorly defined and sod-meadow soils form under these conditions. Ground waters promote gleyization, the accumulation of iron hydroxide, and, under certain conditions, salinization.

In conclusion we must dwell on the problem of the evolution of flood-plain soils of the steppe zone. We analyzed the main groups of flood-plain soils studied and normal chernozem for humus (using the method of Knop), silica, iron, aluminum, calcium, CO₂ carbonates, solid residue, and the thickness of humus horizons in soils of a clayey texture on homogeneous alluvium). The results of these analyses, given in Table 2, show a discrepancy between the values for "humus in percent" and "thickness of the humus layer." Clayey and clayey bog soils are shown to contain a comparatively large amount of humus (2.38%-9.52%), while at the same time the humus horizons in these soils are poorly defined. At least two conditions must be taken into account for these soils. The first is that flood-plain soils develop on alluvium, which already contains humus, even though before it was over-grown by vegetation it did not possess humus horizons (according to our determinations freshly-deposited mud had 1.42%-5.51% humus). The parent material (loess-like clay and clay loam) on which, in this case, meadow-chernozem soils and normal chernozem formed does not contain humus.

In the second place, humus formed under excessive moisture conditions contains more silica and fulvic acids than it does humic acids, which was proved by Kravkov (26), Zakharov (19), and others. The formation of dark soils under conditions of excessive moisture is associated not only with the formation of humus, but also with that of iron compounds and compounds of certain other elements. As known, iron is soluble in the form of hydrotroilite (FeS and H₂S) under anaerobic conditions, which lends a black tinge to the soil mass (23). In addition, silica-iron compounds of the hisingerite group, described by Bogatyrev (4) for meadow soils, is also black. All this leaves an impression on the morphological profile of flood-plain soils. However, in studying these soils in the field, he observes an increase in the thickness of humus horizons as flooding decreases and vegetation changes correspondingly.

Data on other properties of flood-plain soils also show that these soils become more like zonal soils as moisture decreases and vegetation becomes more steppe-like. It was found that in subaquatic and bog soils the indices of quality are very poorly defined. They become more evident in sod-gley soils and distinct in meadow soils on homogeneous alluvium and chernozem-like soils (chernozem-meadow and meadow-chernozem).

An alluvium accumulates in the flood plain and the influence of alluvial and flood-plain pro-

cesses and ground water becomes weaker, the evolution of flood-plain soils falls under the influence of the complex of zonal conditions (soil-formation factors). In this respect the observations made by Shrag (38) on the development of flood-plain soils are very interesting. He writes that "each of these stages is a step in a single soil-formation process, the final result of which are fully formed soils, typical for given physiographic conditions." Shrag shows other stages in the formation of soils, unifying various types of soil in one stage. However, he believes that the final result of the evolution of flood plains are zonal soils, which, in our opinion, is correct.

The types of soils described differ in their agricultural quality, and in the methods that must be used in their agricultural reclamation and use. Subaquatic soils require drainage, the oxidation of reduced compounds, and the building up of a structure if they be used for agricultural purposes. Bog soils require drainage and reclamation and sod-gley and sod-meadow soils, differentiated methods of tillage, depending on the thickness of the humus layer, their texture, the degree in which they are overgrown by vegetation, etc. Selected crops and crop rotation should be used on all reclaimed flood-plain soils. The composition and amount of fertilizer to be used must depend on the properties of these soils.

Received July 10, 1959

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CHEMICAL AND MINERALOGICAL CHARACTERIZATION OF SOILS IN THE CENTRAL PART OF THE KARELIA ISTHMUS

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The soils of Karelia were studied by the method of combined landscape investigation according to Polynov (5, 6, 7). The study took into account the special nature of the processes taking place in the soils of the isthmus, as indicated by various investigators. In particular, the intense removal of organic acids and sesquioxides from the soils was pointed out by Skrynnikova (10). The primary role in the illuviation of Al and Fe of humic compounds of the type of fulvic acids was mentioned by Ponomareva (8). Parfenova and Yarilova (4) pointed to the difficulty in the synthesis of clay minerals in the soil profile and to the accumulation of sesquioxide minerals in the bottom deposits of lakes.

In spite of that, certain problems of soil formation in this region have not been sufficiently studied. They include the problem of the interaction between vegetation and soils. The properties of forest litter have not been fully characterized. The detailed investigations by Rozhnova and Schastnaya (9) on this subject refer to a special landscape in the northwestern part of the isthmus (Vyborg district). There are almost no data on the mineralogical composition of the highly disperse portion of the soil.

Field investigations were made and samples collected by us in the Sosnovskiy district of Leningrad Region, where a series of soil profiles was made from the summit of an esker along its slope and to a small lake terrace. Several samples of new formations were taken from a running-water lake adjoining the terrace. A brief characteristic of the soils is given below.

Profile 1-L was taken at the summit of the esker, which consists of unsorted sandy loam deposits with a large number of small boulders of various sizes. Vegetation consists of spruce and green-moss cover of the following composition: 10 spruces to one birch. The age of the stand is 100-120 years, its site quality index II. Moss is represented by *Hylocomium proliferum* and, to a lesser degree, by *Dicranum undulatum*. Vegetation grows on podzolic illuvial-iron humic soil, the morphological description of which is given below.

A₀' Consists of brown, semi-decayed remains of fir needles, cones, and small branches. The mineral content is small.

A₀" Consists of a homogeneous mass of decayed debris with a considerable mineral content. The forest litter, which is 4 cm thick, abruptly changes into the podzolic horizon.

A₂ 5-12 cm. Whitish. Sandy in texture, loose. There are many tree roots. Becomes darker in the lower portion. The transition to the next horizon is clear in color and texture.

B₁ 13-26 cm. Dark brown. Sandy loam. West blocky structure, compacted. There are less roots than in the podzolic horizon. Transition to lower horizon is gradual.

B₂ 27-52 cm. Brown. Sandy loam, structureless. More compact than the preceding horizon. Fresh. Contains individual tree roots. Clear transition to the next horizon.

C 58-80 cm. Light brown. Sandy loam.

Profile 2-L was taken at the foot of the esker at a distance of 400-500 m from Profile 1-L. The parent material consists of sandy loam deposits, which are underlain at a depth of 50-55 cm by clay loam deposits of a lacustrine-glacial origin. Ground water was found at a depth of 40-50 cm in this profile. Vegetation is represented by meadow associations in which *Deschampsia caespitosa* L., *Agrostis vulgaris* With., *Festuca ovina* L., *Nardus stricta* L., *Luzula pilosa* L., and others predominate. The soil in the 2-L Profile is peaty-humus gley soil, which is briefly described below.

A₀' Weakly decayed leaf-fall of herbaceous vegetation. The total thickness of A₀' and A₀" is about 6 cm.

A₀" Peat-like herbaceous litter of a gray-brown color. There is a large amount of mineral particles in the lower portion.

A₁ 7-19 cm. Dark gray in color. Weak blocky-powdery structure. Sandy loam. Loose. There are many roots of herbaceous plants. Moist. The lower portion of the horizon is less tinted by humic substances.

Bg 20-40 cm. Uneven in color: dark-blue spots resulting from gleyization on a brown background. Sandy loam, loose. There are many roots. Structureless.

Samples of bottom deposits were taken 2 m from the shore of the small running-stream. The lake clay is compact and smeary. It is like fine clay loam in texture and of a dark brown color, containing a considerable amount of semi-decayed plant tissue and concretions of lake ore in bead form 5-7 mm in diameter, sometimes cemented together. The lake water is soft and brown with "rusty-brown sediments."

Granitic-gneiss boulders are a characteristic part of the landscape. Their bare surfaces are subject to atmospheric weathering and weathering by the shrub-like lichen *Cladonia*. Data in Table 1 give an idea of the nature of the weathering of granitic gneiss.

Lichen has a considerably high ash content (up to 5%). Ca, Si and K predominate among the ash elements. A comparison of the ash content of lichen with that of granitic gneiss shows the intense participation in the biological cycle of P, Ca, K, and, to a lesser degree, Mg. Si, Al and Fe do not concentrate in lichen.

Fine earths, accumulating under lichen, undergo a great loss by ignition (up to 50%). About two thirds of the fine earths consist of fractions $<1 \mu$ in diameter. As compared to the granitic gneiss, an accumulation of Ca, P, Mg, Al and Fe was found in the fine earths, while their content in K, Na and S decreased. A comparison with the ash composition of lichen shows an increase in the Fe, Al and Si content in the fine earths. Simultaneously, the time that P, K, and Ca are contained in the fine earths sharply decreases.

The ignition loss of the $<1 \mu$ diameter fraction, separated from the fine earths is 83%. An accumulation of Fe, Al, P and Mg was found in the clay fraction as compared to the granitic gneiss. The content of other elements, including Si, decreased noticeably. As compared to the ash content of *Cladonia*, the content of all elements, except Al and Fe, decreased.

In the products of weathering of granitic-gneiss, the magnitude of the molecular ratio of $Al_2O_3:Fe_2O_3$ ¹ decreases. The ratio of $SiO_2:R_2O_3$ decreases regularly from the series: granitic gneiss - lichen - fine earths - the $<1 \mu$ diameter fraction of the fine earths.

The K, Mg, S and P content in the spruce needles (Table 2) is considerably higher than in the parent material, while the Al and Si content is lower.

The decomposition of the tree litter-fall is accompanied by a certain increase in ash content. Judging by the change in the chemical composition of the A_0' and A_0'' horizons, an accumulation of Al and Si occurs. The K is especially intensively leached from the decaying litter-fall, while Ca, Mg and P are leached to a lesser degree.

The Fe content is somewhat lower in the A_0'' horizon than in the A_0' horizon, which shows

how mobile Fe is. This is the difference between the decomposition of forest litter in the area studied and that under conditions in the Moscow Region. While the accumulation of nutrients in the green-moss spruce stands of the Moscow Region is accompanied by their biological accumulation in the upper part of the soil profile, the forest litter in the isthmus of Karelia is immediately underlain by a horizon characterized by its low content in K, S, Ca, P and Mg. This is caused by differences in the nature of the decomposition of plant residue, as well as by a different composition of humic substances which form when plant residues decay. Fulvic acids characteristically predominate in the soil humus of the isthmus of Karelia, promoting the removal from the soil not only of alkali and alkaline earth cations, but also of poorly soluble Si, Al and Fe compounds (8). In the soils of the Moscow region, on the other hand, humic acids predominate in humic compounds (3).

The active reaction of the soils is acid. Because of its high mobility, the maximum content of humus is found in the B_1 horizon. The upper soil horizons are characteristically low in clay particles. The particle content of the $<1 \mu$ diameter increases with depth, reaching a maximum in the B_2 horizon. Sesquioxides are removed to a considerable degree from the upper horizon and the silica content increases correspondingly. The impoverishment of the upper portion of the soil profile in Ca, Mg, K, S and P testifies to the presence of the podzolic process in these soils. An increase in the Mg and P content is noted in the illuvial horizon as compared to the parent material.

V. V. Ponomarev (8) considers soils with an analogous morphological profile and composition as being illuvial-iron humic podzolic soils. These soils are characteristic of large portions of the isthmus of Karelia. Total chemical analysis of clay fractions, separated from these soils, revealed a considerable content (especially in the illuvial horizon) of sesquioxides, which is shown by the change in the $SiO_2:R_2O_3$ ratio along the soil profile. The magnitude of this ratio (2.5-3.2) may indicate that the content of non-silicate Al and Fe is high, or that the composition of the clay fraction is kaolinitic. This is substantiated by the comparatively low exchange capacity, the magnitude of which along the soil profile reflects the distribution of sesquioxides and the change of the composition of the clay portion of the $<1 \mu$ diameter fraction. The accumulation of non-silicate Al and Fe is substantiated by the fact that they are dissolved in appreciable quantities by treatment with 10% HCl (Table 6).

Thermographic investigations of the clay fractions (Fig. 1) show that the soil colloids are highly hydrophilic (endothermic effect at 100-115°C), which is determined by their content in amorphous compounds and humic matter. Complete oxidation of the organic portion was not achieved by treatment of the samples with H_2O_2 , which testifies to the presence of a considerable amount of organo-mineral compounds. This is the reason for the high exothermic effect at temperatures from 275-325°C. The content of such compounds decreases with depth. In conformity with the results of chemical investigations, the thermograms revealed endothermic

¹ For the sake of brevity we will not write: $SiO_2:R_2O_3$ ratio or $Al_2O_3:F_2O_3$ ratio.

Sample	Ignition loss	Content of the <1 μ in diameter	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅	Total	Molecular ratio	
													SiO ₂ /R ₂ O ₃	Al ₂ O ₃ /Fe ₂ O ₃
"Fresh" granitic gneiss	0,00	---	66,58	15,09	4,47	19,56	3,24	1,70	3,19	3,09	0,13	97,46	6,87	7,00
Lichen <i>Cladonia</i>	7,85 ^a	---	24,29	6,41	3,00	9,50	34,91	6,18	12,38	4,72	3,84	95,82	5,71	2,50
Fine earths under lichen	54,03	61,5b	59,03	18,35	6,72	25,07	6,85	3,22	2,84	2,11	0,46	99,58	4,45	4,50
<1 μ diam. of fine earths	83,04	---	45,62	21,05	16,31	37,36	4,01	4,87	2,84	2,03	0,67	97,40	2,50	2,00

^aAsh in percent of sample, dried at 70-75°C.^bSeparation of the <1 μ diameter particles by repeated decantation.

Table 2

Chemical composition of spruce needles, forest litter and soil horizons, as well as of their <1 μ diameter particles, % of ignited matter

Sample	Depth, cm	Ignition loss	<1 μ diam. particles	pH of water suspension	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	CaO	MgO	K ₂ O	P ₂ O ₅	SO ₂	Total	Molecular ratio		Exchange capacity meq/100 g of fraction
															SiO ₂ /R ₂ O ₃	Al ₂ O ₃ /Fe ₂ O ₃	
Fresh pine needles		3,56 ^a	---	4,7	45,39	3,92	4,18	8,10	29,83	6,41	4,93	3,13	3,05	100,84	15,0	1,5	Not detd.
Forest litter	0-4	4,80 ^a	---	4,2	57,14	10,37	6,20	16,57	18,06	3,24	2,14	2,22	2,40	99,77	6,8	2,5	---
		4,72 ^a	---	3,8	60,03	25,45	5,68	34,13	4,03	0,96	0,49	0,49	1,04	98,04	3,7	8,0	---
	4-12	1,60 ^b	5,09	3,9	90,48	7,85	0,78	8,63	0,52	0,10	0,09	0,12	0,09	100,03	18,75	19,0	---
	15-25	4,13 ^b	7,84	4,5	83,61	12,98	1,90	14,88	0,82	0,44	0,12	0,23	0,13	100,23	10,69	12,0	---
	40-50	3,00 ^b	12,13	4,5	87,19	10,43	4,69	12,12	4,35	0,26	0,17	0,18	0,27	100,54	13,18	10,0	---
<1 μ diameter particles from horizons	70-80	0,40 ^b	10,40	5,3	85,70	10,73	1,73	12,46	1,15	0,25	0,13	0,14	0,05	99,88	12,90	10,0	---
	4-12	14,84	---	---	60,03	28,31	7,03	35,34	0,50	3,41	0,45	0,40	0,51	100,34	3,19	6,75	26,3
	15-25	4,95	---	---	52,14	27,45	14,29	41,74	0,49	3,68	0,63	0,55	0,34	99,57	2,52	3,25	33,8
	40-50	8,63	---	---	54,28	32,70	8,53	44,23	0,58	2,93	0,50	0,48	0,39	100,39	2,51	6,40	30,9
	70-80	3,48	---	---	56,98	26,05	12,18	38,23	0,62	3,44	0,57	0,23	0,18	100,02	2,93	3,57	45,0

^aAsh content, in % of substance, dried at 70-75°.^bHumus content (according to Tyurin), in % of absolutely dry sample.

Note: Comma represents decimal point.

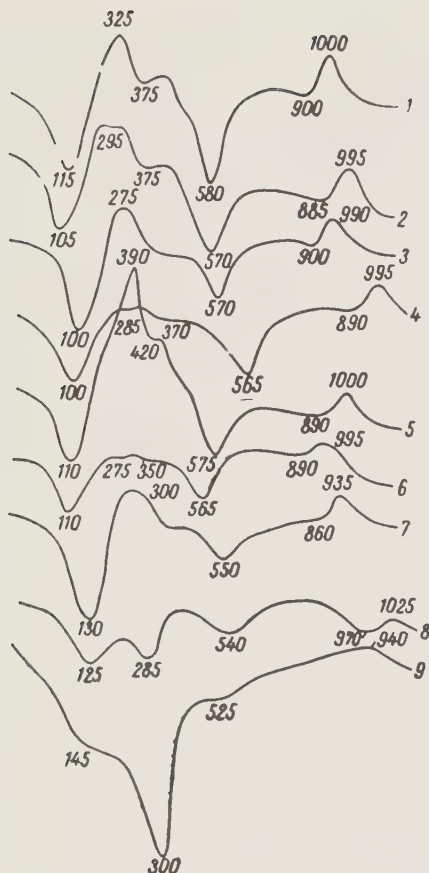


Fig. 1. - Thermograms of $<1 \mu$ diameter fractions of soils and certain lake formations in the central part of the isthmus of Karelia.

Podzolic humo-iron-illuvial soil: 1 - A₂ horizon, 5-12 cm; 2 - B₁ horizon, 15-25 cm; 3 - B₂ horizon, 40-50 cm; 4 - C horizon, 70-80 cm. Peaty humus-gley soils: 5 - A₁ horizon, 7-16 cm; 6 - B horizon, 2-30 cm. Bottom deposits: 7 - clay; 8 - concretions of lake ore; 9 - cemented concretions of lake ore.

peaks as a result of the presence of hydro-goethite (285-375°C). Further, the thermograms of all samples show a complex of thermal effects, pointing to the presence of clay minerals. The endothermic peak at 565-580°C and the exothermic peak at 995-1000°C testify to the presence of kaolinite and montmorillonite, especially in the upper part of the soil profile. Judging by the thermograms, the mineralogical composition of the fraction changes with depth, possibly because of the increase of minerals of the montmorillonite group.

The mineralogical composition of clay fractions in the soil studied differs greatly from the composition of soil colloids in the sod-podzolic soils on surface and morainic clay

loams of European USSR studied by Gorbunov (1, 2).

The grass vegetation is characterized by its high ash content.²

As compared to spruce needles, grasses have a markedly higher content of Mg and especially K (Table 3). The content of Ca in the ash of grasses proved to be two times lower than in the spruce needles.

The decomposition of plant residue is accompanied by an especially intense leaching of K and S, as may be seen from a comparison of the chemical composition of grass and that of the A₀' and A₀'' horizons of the soil. The content of P, Ca and, especially, Mg decreases less sharply during the process of mineralization. At the same time, a relative accumulation of Si, Al and Fe occurs. The Al₂O₃:Fe₂O₃ ratio in the ash of living grasses and their residue is considerably higher than in the spruce needles and in the spruce and green moss forest litter.

Meadow soil is characterized by a high content of humus in the upper horizon. Humus decreases considerably with depth along the soil profile. This soil is also characterized by a high content of the clay fraction, whereby the particle content of $<1 \mu$ in diameter in the humus-accumulating horizon is higher than in the underlying horizon. Judging from total chemical analysis data, Mg and Ca accumulate in the upper soil horizon. The Fe content along the soil profile is almost constant, while Al accumulates in the illuvial horizon. The active reaction of the soil is less acid than in the soil in Profile 1-L.

The total chemical composition of clay fractions in the two horizons of the meadow soil differs considerably from the composition of the $<1 \mu$ diameter particles of the soil in Profile 1-L. It was determined, in particular, that its Al and Fe content is higher, while the Si content is lower. Similar values were obtained for Mg. The content of K and Ca, however, in the $<1 \mu$ diameter particles of the soil in Profile 2-L is considerably higher than in podzolic soil. The SiO₂:R₂O₃ ratio, which does not exceed 1.6, points to a different composition of clay mineral fraction as compared to Profile 1-L.

Heating curves for the clay fractions have an endothermic effect at 110°C, indicating that they are highly hydrophilic. The large exothermic peak at 390°C must be attributed either to the high content in organic compounds, which were not destroyed on treatment with H₂O₂, or to the presence of amorphous hydrates of ferric oxides. The latter is substantiated by the high content of Fe, which is soluble in the Tamm's reagent and in 10% HCl. Endothermic effects at 275-420°C point to the presence of hydro-goethite in the samples investigated. The temperature and nature of the next endothermic effect (565-575°C) and thermal peaks at 890

² Ash content of grass cover is determined in an average sample of three cuttings from an area 25 x 25 cm.

Table 3

Chemical composition of grass, plant residue, soil and the <1 μ diameter fraction (Profile 2-L), % of ignited matter

Sample	Depth, cm	Igni- tion loss	pH of water suspension	Content of particles <1 μ dia., %	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	CaO	MgO	K ₂ O	P ₂ O ₅	SO ₂	Total	Molecular ratio		Exchange capacity meq/100 g of fraction	
															SiO ₂ R ₂ O ₃	Al ₂ O ₃ Fe ₂ O ₃		
Grass cover																		
Grass litter	{ A' % A'' % A ₁ A ₂ B _g B ₁	— 0-3 3-6 7-16 20-30 7-16 20-30	6,18 ^a 9,80 ^a 12,44 ^a 7,75 ^b 2,73 27,41 19,07	5,3 5,1 4,6 5,2 5,3 — —	— — — 14,5 12,7 — —	48,07 77,00 79,81 85,09 83,27 39,14 41,50	4,89 15,54 15,96 8,23 10,79 34,30 38,17	1,24 2,84 2,63 3,14 3,02 16,83 12,75	6,13 18,38 16,59 11,37 13,81 51,13 50,92	15,81 7,34 1,45 0,93 0,81 2,09 2,50	10,43 4,03 1,69 1,43 0,68 3,69 3,42	12,05 0,65 0,11 0,10 0,08 1,81 1,50	3,41 0,64 0,26 0,09 0,10 0,43 0,36	3,90 0,31 0,09 0,05 0,05 — —	99,70 98,35 100,00 99,06 98,80 98,29 100,20	14,79 8,0 8,25 14,10 11,5 1,51 1,56	7,83 15,0 15,0 4,0 5,0 3,3 5,3	Not det'd. — — — — 45,8 42,5

^aAsh content, in % of substance, dried at 70-75°C.^bHumus (according to Tyurin), in % of absolute dry sample.

Table 5

Characteristics of certain forms of new formations in the subaqueous element of the landscape, % of ignited substance

Sample	Ignition loss	Hu- mus, %	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	CaO	MgO	MnO	K ₂ O	P ₂ O ₅	Total	Molecular ratio			Exchange capacity meq/100 g
													SiO ₂ R ₂ O ₃	Al ₂ O ₃ Fe ₂ O ₃		
<1 μ diam. particle from stream clay	17,43	—	50,35	29,80	12,91	42,71	0,83	3,14	Not det'd	2,19	0,27	99,49	2,12	2,90	40,2	
Fresh portion of pebbles	0,00	—	68,14	18,32	4,13	22,45	3,11	1,63	—	3,21	0,09	98,63	5,24	8,50	—	
Crust on pebbles	16,75	—	49,31	23,56	29,04	45,60	2,19	0,84	—	1,01	0,21	99,16	2,00	1,27	—	
Concretions of bog ore	14,12	8,49	41,83	10,34	33,41	44,35	4,55	2,04	6,03	0,43	0,39	99,52	2,39	0,50	—	
<1 μ diam. particle from concretions	31,05	—	20,52	18,73	47,90	66,63	2,75	4,19	5,16	1,70	0,51	101,46	0,72	0,62	25,5	
Cemented concretions	12,34	7,03	45,92	42,03	49,18	46,21	2,07	3,12	3,61	0,57	0,21	101,71	2,45	0,55	—	
<1 μ diam. from cemented concretions	27,52	—	28,42	16,84	40,58	57,42	1,89	4,23	5,55	1,90	0,30	99,71	2,30	0,80	28,3	

Note: Comma represents decimal point.

Table 4

Chemical composition of waters in the landscape, mg/liter

Sample	Dry residue	pH	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	CaO	MgO	SO ₃
Ground water (Profile 2-L)	241	5,61	18,3	1,0	2,8	3,8	31,3	7,9	5,0
Stream water	298	5,83	15,0	0,5	2,5	3,0	30,4	4,9	3,5
Lake water	290	5,70	19,2		1,0	1,0	22,7	5,8	5,2

Note: Comma represents decimal point.

and 1000°C, together with the high exchange capacity and a high content of K, show the complex composition of the <1 μ diameter particles. The presence of minerals of the montmorillonite and hydromica groups with an addition of minerals of the kaolinite group must be assumed.

Ground water was found at a depth of 40-45 cm in the 2-L Profile, the results of the chemical analysis of which are given in Table 4. Table 4 also gives data on the chemical composition of lake and stream water in the landscape studied. The active reaction in all water samples was acid. A high Ca content was found in the ground and stream water. The Ca content was much smaller in the lake water. All samples had approximately the same amount of S and Mg. Taking into account the low content of the mentioned elements in the parent material, their intense removal as a result of weathering and soil formation must be assumed. Si was also found highly mobile, even though it was less mobile than the other elements. The Fe₂O₃ content in the water samples did not exceed 3 mg/liter, and that of Al₂O₃, 1 mg/liter. Their maximum was found in the ground water.

These data indicate that Fe is much more mobile than Al, which is apparently due to its ability to migrate in the bivalent form. In this respect the data on bottom deposits in the running stream to the lake are of certain interest (Table 5).

Total chemical analysis of the clay fraction, separated from lake clay, shows a high content of sesquioxides. The Al₂O₃:Fe₂O₃ ratio testifies to the preferential accumulation of Fe in it in contrast to meadow soil, where Al accumulates especially intensively. The K content is considerable. The exchange capacity is 40 meq. Thermographs reveal a high content of amorphous compounds and organic substances. The endothermic peak at 350°C points to a considerable content of hydrogoethite. The presence of the hydromica mineral testifies to the high content of potassium oxide. The heating curve (Fig. 1) substantiates this.

Almost half of the lake ore concretions consists of sesquioxides. The content of ferric oxide reaches 30%-38%. The content of Mn is very high (up to 6%). In conformity with this, the Si content is low. The Al₂O₃:Fe₂O₃ ratio testifies to the preferential accumulation of Fe. As compared with the parent material in Profile 1-L, concretions of lake ore contain 15 times more Fe and also much more Ca, Mg,

K, P and S. The Al content is the same. The high content of humus testifies to its participation in the formation of lake ore.

There is more Fe, P, Ca and Mg in the clay fraction of lake ore than in the <1 μ diameter fraction of the parent material in Profile 1-L (Table 2). There is no substantial difference in the Al and Si content. As compared to the <1 μ diameter particles in lake clay, the Fe and Ca content is higher in the clay fraction of lake ore, while the content of other elements is lower. Of all samples investigated the clay fraction of concretions had the lowest SiO₂:R₂O₃ and Al₂O₃:Fe₂O₃ ratios.

The data examined indicate that an accumulation of Fe and Mn, as well as of organic substances, occurs in the bottom deposits of the lake.

Thermograms of the <1 μ diameter fraction of lake ore show an endothermic effect at 125°C, which indicates that the samples are very hydrophilic. Further, there is a well-defined endothermic effect at 285-300°C, which testifies to a high content of hydrogoethite.

In conformity with the chemical analysis, the maximum content of hydrogoethite is found in the cemented concretions. The endothermic peak at 525-540°C points to the presence of a clay mineral, possibly of the kaolinite group. The noticeable content of potassium oxide may indicate the presence of a hydromica mineral. In conformity with the high Fe and Al content, the exchange capacity of the new formations studies is very low.

Data in Table 6 indicate the change in the chemical composition of the highly disperse portion of illuvial horizons at the transition from podzolic to meadow soils and also the lake bottom deposits.

Let us briefly examine these data. About one-third to one-half of all sesquioxides is soluble in 10% hydrochloric acid. The amount of Fe removed in this extract, as compared to its total content, is much higher than that of Al. The Si content is small. A considerable accumulation of sesquioxides was found in the clay fractions of illuvial soil horizons, in lake clay and in lake ore. If Al concentrates predominantly in the <1 μ diameter fraction of the illuvial horizon of Profile 2-L, Fe predominantly concentrates in the lake clay and lake ore concretions. In conformity with this,

KARELIA ISTHMUS SOILS

Table 6

Characteristics of the chemical composition of clay fractions in soil, in lake clay and in concretions of lake ore, % of the ignited sample

Sample		SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃ + Fe ₂ O ₃	Total	Molecular ratio	
							SiO ₂ / R ₂ O ₃	Al ₂ O ₃ / Fe ₂ O ₃
<1 μ diameter fraction Profile 1-L, C horizon 70-80 cm	I ^a	56,98	26,05	12,18	38,23	95,21	2,9	3,6
	II	10,36	5,84	5,60	11,44	22,80		
	III	0,93	1,50	1,30	2,80	3,73		
<1 μ diameter fraction Profile 1-L, B ₁ horizon 15-25 cm	I	52,14	27,45	14,29	41,74	93,88	2,5	3,25
	II	9,61	7,27	9,13	16,40	27,01		
	III	0,88	1,35	1,56	2,91	3,79		
<1 μ diameter fraction Profile 2-L, B _{g1} horizon 20-30 cm	I	41,50	38,17	12,75	50,92	91,22	1,56	5,3
	II	6,54	15,43	9,29	24,72	31,26		
	III	1,07	2,93	1,85	4,78	5,85		
<1 μ diameter fraction Lake clay	I	50,35	29,80	12,91	42,71	93,06	2,1	2,9
	II	7,70	8,15	10,08	20,23	32,93		
	III	1,15	3,06	2,47	5,53	6,68		
<1 μ diameter fraction Lake ore (concretions)	I	20,52	18,73	47,90	66,63	87,15	0,72	0,62
	II	2,13	10,17	39,41	49,58	81,71		
	III	1,57	3,65	6,22	8,87	11,44		

^aL. Total content of sesquioxides and silica; II. R₂O₃ and SiO₂ content, soluble in 10% HCl (SiO₂ sum soluble in 10% HCl and in 5% KOH); III. R₂O₃ and SiO₂ content soluble in Tamm's reagent (for sandy soil).

Note: Comma represents decimal point.

a tendency was found for the SiO₂:R₂O₃ and Al₂O₃:Fe₂O₃ ratios to decrease.

Sesquioxides and silica, which are soluble in the Tamm's reagent are similarly distributed, with the exception that the clay fractions of meadow soil and lake bottom deposits have a higher content of soluble Si. Both methods give similar results as far as the predominant concentration of mobile forms of Fe in the <1 μ diameter fraction of lake clay and lake ore and the predominant concentration of mobile Al in the clay fraction of the illuvial horizon of the 2-L Profile as concerned. These data together with the data examined earlier may indicate a high migration ability of Fe as compared to Al.

Conclusions

1. The weathering of massif crystalline rocks under the influence of the lichen *Cladonia* has a siallitic character and is accompanied by the intense removal of S, K and Ca, and to a lesser degree Mg and Si. Al and Fe accumulate in the products of weathering.

2. An intense concentration of K, P, Ca and Mg occurs in spruce needles. The decay of litter-fall in the forest is accompanied by the intense removal of these elements and an increase in SiO₂ and R₂O₃ content. Podzolic illu-

vial-humus-iron soils form under these conditions, the clay minerals of which are represented by a mixture of kaolinite and montmorillonite groups, whereby the content of montmorillonite increases in the lower soil horizons.

3. K, S, P and Ca are intensively involved in the biological cycle of the meadow vegetation. The decomposition of litter-fall is accompanied by a higher accumulation of Al than Fe. Meadow-like soil with a high content of humus and a concentration of R₂O₃ in the illuvial horizon form under these conditions. Al accumulates to a higher degree than Fe. The highly disperse part of the soil is represented by amorphous compounds of R₂O₃ and by hydrogoethite, while the clay portion is represented by a mixture of minerals of the montmorillonite, hydromica and kaolinite groups.

4. Mn, Fe and Al accumulate in lake clay and lake ore, whereby, in contrast to the meadow soil, more Fe than Al accumulates in the bottom deposits, which indicates the high migration ability of Fe. Fe accumulates primarily in the form of hydroxide gel and hydrogoethite. The portion of Fe in the form of hydrogoethite increases considerably in cemented new formations. A clay mineral was found, probably hydromica.

Received October 29, 1959

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CHANGE IN SOIL MELIORATIVE CONDITIONS AFTER DIKING THE VOLGA-AKHTUBA FLOOD PLAIN

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In the delta of the Volga and Volga-Akhtuba flood plain, dikes are frequently erected around individual areas in order to protect the soil from inundation during floods. The reason for this is the fact that the high water period is very prolonged (to July) in the lower reaches of the Volga River, so that under usual conditions the land can be used only for late crops.

Diked areas do not become inundated during the flood period so that they are used for grain and vegetable crops. The land can be used either with or without irrigation, depending on local conditions such as the quality of soils, the depth of the ground-water table, etc. In both cases the water regime of the soils, established before the dikes were erected, is disturbed. The leaching regime, characteristic of flood-plain lands, is practically altogether absent. If ground water is near the surface (and continually recharged), a seepage regime develops, which is usually associated here with salinization. In areas where the ground-water table is deep, soils dry up and become steppe-like. Both these types of soil development are unfavorable in the highly arid climate of the Lower Volga region.

Practice has shown that part of the diked areas may successfully be used for crops for a long time, but many of them rapidly become unsuitable for agriculture. The reason for this is most often the rapid and intense salinization of diked lands as a result of the change in their water and salt regime after inundation ceases.

A knowledge of the causes and conditions of salinization of diked lands is very important in the selection of new areas, as well as in the utilization of existing areas. This is why a study of various forms of water-salt regimes under various conditions in diked areas is so important. For this purpose, from 1958-1959 we investigated one of the diked areas of the southern part of the Volga-Akhtuba flood plain.

The area investigated is located on the left bank of the Akhtuba River in the sovkhos Akhtuba in the Krasnoyarsk district of Astrakhan' Region (Fig. 1). The diked area is bordered by the valley side in the north and east and by the Akhtuba River and its tributary, the Kuenlyshka River, in the south and west. It is 6 km long and 0.5-0.3 km wide and covers an area of 110 ha. The area was diked in 1952.

Geomorphologically the area is located between the river and the upper edge of the terraces. This is a flat valley, generally sloping to the south-southeast, changing near the river into river banks and ridges. The central part of the area is crossed from the NW to the SE by a wide, shallow depression. In the NE and SE parts of the sovkhos there are a number of sloughs and oxbow lakes which dried out after the area was diked. The area has not been irrigated for three years after it had been diked. Since 1956, 270 ha of the area have been irrigated annually.

The area consists of recent and old alluvium lying on eroded bedrock of the Baku stage. The parent material consists of salinized alluvial clay loams and clays, underlain from a depth of 3-4 m by sand. The salinization of the soil is of the chloride-sodium and chloride-sulfate-magnesium-calcium types with a solid residue of 0.5%-2.0% (Table 1). The soils along the river form on non-saline alluvial clay loams and sandy loams.

Before the dike was erected, the most salinized soils were found in the depression and in the southeastern oxbow lake, where flood-plain meadow solonchakized soils and wet meadow solonchak of the chloride-sodium type formed as a result of the proximity of mineralized ground water (9). The central and north-eastern parts of the area were occupied primarily by solonchak-like flood-plain meadow soils with a chloride-sulfate-magnesium-calcium type of salinization. Non-saline soils were found primarily along the Akhtuba River.

Vegetation before the area was diked (8) was represented by mixed grass-sedge and mixed herb-grass associations in which Agropyrum repens, Carex schreberi and Bromus inermis predominated. The oxbow lakes were dominated by Carex gracilis associations and Heleocharis palustris associations. Halophytes, such as Salicornia herbacea, Salsola ruthenica and Salsola collina were widely distributed over the moist meadow solonchak.

Investigations conducted in 1958 by the geobotanist Rodman (7) showed that after the dike was erected the mixed grass-sedge and mixed herb-grass associations, in which Agropyrum repens, Carex schreberi and Bromus inermis predominated, were replaced primarily by the



Fig. 1. - Schematic plan of the diked area.

1 - boreholes; 2 - profiles; 3 - dike.

association of *Artemisia austriaca*, *Atriplex tatarica*, *Bromus tectorum* and *Aeluropus litoralis*. As a result of the drying and salinization of oxbow lakes, log-meadow vegetation (acc. *Carex gracilis* - *Heleocharis palustris*) was replaced by associations of *Atriplex tatarica*, while on the wet meadow solonchak *Salicornia herbacea* was replaced by *Suaeda prostrata*.

Undoubtedly the change in vegetation was the result of the new hydrogeological regime and the cessation of the inundation of the area by flood waters. These conditions indicate the beginning of steppe formation and saline soils.

Before the dike was built, ground waters belonged to two types: alluvial-infiltration water, fed by spring floods, and ground waters derived from the Khvalynsk deposits of the shore side. According to data of the Rostov-on-the-Don Branch of the Giprosovkhovod (State Institute for Planning Soviet Economy, and Water Resources) (6), ground water was found at a depth of 1.5-4.0 m in the level portion of the area and at 0.5-1.5 m in the sloughs and oxbow lakes on November 29, 1951. The balance of ground water during annual floods in the valley portion of the area was regulated by subsurface runoff and the transpiration of plants, while that in the oxbow lakes was regulated by evaporation and transpiration.

Investigations on the ground-water regime, conducted by the Rostov Branch of the Giprosovkhovod the first year after the area had been

diked (from May 1953-April 1954), showed that the influence of floods on ground water was felt at an average distance of 350 m from the dike (10). As may be seen from Figure 2, the ground-water table in the water barrier zone begins to rise in early June and reaches a maximum in the second part of July. The ground water stays at a high level from 40-45 days. The ground-water table gradually falls in September and reaches a minimum at the end of October. The maximum rise of the ground-water table lags behind the rise of river water by a month and a half. The peak rise of the ground-water table characteristically coincides with the low-water stage of the Akhtuba River. The amplitude of ground-water table fluctuations in the zone of water-barrier at a distance of 200 and 500 m from the dike is 0.60 and 0.15 m, respectively.

It must be noted that within the first year after the area had been diked the temporary water table was lowered by 0.8-1.1 m in the sloughs and oxbow lakes (Fig. 3) and by 0.2-0.3 m in the valley. Hydrogeological and soil melioration investigations made by the Yuzhgiprovodkhov (Southern State Institute for Planning of Water Economy) in the second half of October 1958 revealed that within five years the ground-water table lowered an average of 1 m in the level area, except for that under the influence of the Akhtuba River, and 1.5 m in the sloughs and oxbow lakes, as compared to where it stood before the area was diked.

Table 1
Mineralization (g per liter) and chemical composition of river and ground waters in chronological order of sampling

Location of taking soil samples	Borehole and profile No.	Depth of ground water, m	Date	Dry residue	HCO ₃	Cl	SO ₄	Ca	Mg	N + K by difference	Chemical relation of river and ground water				Mg/Ca
											Cl	HCO ₃	SO ₄	Na + K Ca + Mg	
Akhtuba River Area near the river in the zone of influence of Akhtuba River	2 4	1,9 3,1 2,5 3,2	Sept. 25, 1959	0,280	0,122	0,051	0,054	0,050	0,016	0,016	1,2	0,7	1,2	0,2	0,5
			Sept. 1, 1953	0,36	0,18	0,05	0,03	0,06	0,02	0,02	2,5	1,5	2,5	0,2	0,4
			May 3, 1953	1,52	0,47	0,43	0,15	0,15	0,07	0,23	3,5	0,5	3,5	0,8	0,8
			Sept. 1, 1953	2,09	0,83	0,53	0,13	0,16	0,03	0,34	5,4	0,7	5,4	0,9	0,9
Dry slough near the irrigated area	7	3,0	Oct. 25, 1953	2,60	0,83	0,64	0,14	0,19	0,10	0,39	4,2	0,7	4,2	0,9	0,9
			Apr. 27, 1959	1,56	0,63	0,38	0,10	0,25	0,06	0,14	5,1	0,7	5,1	0,3	0,4
			May 3, 1953	2,31	0,80	0,80	0,08	0,17	0,11	0,35	4,4	0,5	4,4	0,3	1,0
			Sept. 1, 1953	2,33	1,40	0,61	0,05	0,15	0,12	0,30	11,3	1,3	11,3	0,8	1,1
Central level portion of the area	1	2,8	Oct. 25, 1953	2,65	1,45	0,81	0,06	0,16	0,13	0,29	10,3	1,5	10,3	0,7	1,0
			Apr. 27, 1959	3,56	0,78	1,25	0,72	0,72	0,18	0,26	2,3	0,2	2,3	0,2	0,5
			Nov. 1, 1950	12,47	0,38	6,40	1,27	0,88	0,38	3,45	6,8	0,03	6,8	1,8	0,7
			Nov. 23, 1958	11,36	0,27	5,75	1,33	1,36	0,82	1,34	5,9	0,02	5,9	0,4	0,9
a) irrigated since 1956 b) non-irrigated	8 5	2,5 3,8	Sept. 27, 1951	27,22	0,30	13,77	2,34	1,99	1,51	5,02	7,9	0,009	7,9	0,7	1,2
			Sept. 25, 1958	28,40	0,28	13,68	2,45	2,32	1,65	4,35	7,5	0,009	7,5	0,7	1,1
			Nov. 5, 1950	17,94	0,24	7,55	2,05	1,21	0,42	3,78	5,3	0,1	5,3	1,7	0,5
			Sept. 25, 1958	27,46	0,18	16,59	4,47	2,60	1,76	5,06	19,5	0,006	19,5	0,8	1,1
Dry oxbow lake in the zone of influence of mineralized ground waters derived from main shore	23 25	1,2 2,0 1,8	Sept. 1, 1953	1,54	0,33	0,42	0,30	0,11	0,04	0,34	1,7	0,3	1,7	1,6	0,5
			Apr. 27, 1959	33,76	0,26	21,11	0,77	3,07	2,32	6,23	37,0	0,006	37,0	0,8	1,2
			Apr. 27, 1959	21,38	0,39	13,24	0,44	1,45	1,39	4,63	41,4	0,01	41,4	1,0	1,5
			Apr. 27, 1959	23,81	0,34	14,86	0,48	3,34	1,36	3,56	41,9	0,008	41,9	0,8	0,6
Periphery of oxbow lake	21	1,9	May 3, 1953	25,59	0,18	11,30	2,31	2,08	0,83	2,08	6,6	0,002	6,6	0,2	0,5
			Sept. 1, 1953	16,57	0,66	8,45	0,66	1,85	0,43	5,19	2,4	0,004	2,4	0,2	0,5
			Sept. 23, 1951	27,49	0,58	12,35	4,47	0,84	0,96	7,59	3,7	0,02	3,7	2,7	1,8
			Sept. 25, 1958	18,93	0,51	10,12	1,23	0,64	1,37	4,94	10,4	0,02	10,4	2,6	2,1
At the boundary of the main shore	6	0,9	Nov. 26, 1951	38,24	0,33	20,63	2,52	2,59	1,90	8,18	41,1	0,007	41,1	1,9	1,2
			May 3, 1953	33,30	0,30	16,89	1,74	1,96	0,82	8,01	13,1	0,008	13,1	2,1	0,7

Note: Comma represents decimal point.

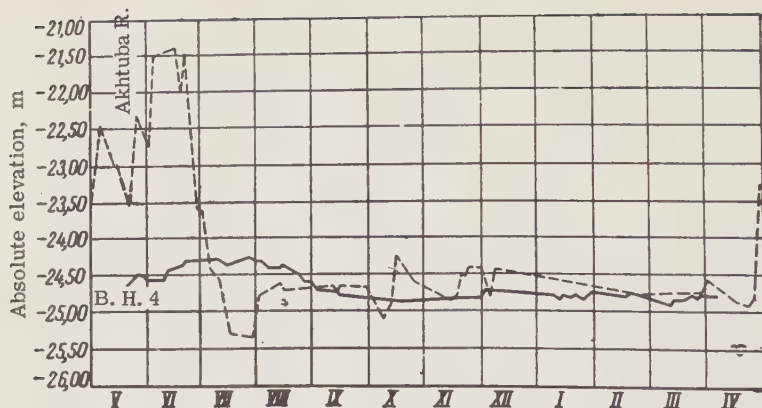


Fig. 2. - Curve of the fluctuation of the ground-water table (borehole 4) in the zone of water barrier of the Akhtuba River, May 1953-April 1959, (according to data of I.I. Tikhomirov).

The ground-water regime prevailing in the area before it was diked (which was compensated by subsurface runoff and plant transpiration in the level area and transpiration and evaporation in oxbow lakes) changed after the dike was built into a negatively decompensated (according to Kovda, [2]), ground-water regime as a result of the cessation of recharge by flood waters.

The mineralization of the ground water varied from 0.36-38.24 g/l before the area was diked. The lowest mineralization (0.36-1.54 g/l) was found in the zone of influence of the Akhtuba River (boreholes 2, 4) and in the upper ground-water layer (surface water) of the oxbow lakes (borehole 23), lying above the highly-mineralized (38.30 g/l) ground water derived from the main shore (borehole 26). In the central and northeastern parts of the area within the influence of these waters, the degree of mineralization of the ground water reached 27.22-38.24 g/l. The ground waters near the river and in the central parts of the area belonged to the chloride-magnesium-calcium and chloride-calcium-sodium type of salinization (4), while those in the oxbow lakes belonged to the sulfate-chloride-calcium-sodium and chloride-sodium types.

The ground waters of the valley side belonged to the chloride-sodium type of salinization (borehole 26). The chemical composition of ground waters near the river (Table 1) indicates their close relation to the water of the Akhtuba River. With distance from the river, the mineralization of ground waters in the zone of influence of the river increases to 2.31 g/l (borehole 7) and their qualitative composition changes in favor of the chlorine ion, HCO_3 and sodium.

In the process of evaporation within the soil (3) the mineralization of ground waters near the river increased from 1.52 to 2.60 g/l (borehole 4) and from 2.31 to 2.65 g/l (borehole 7) from June to October after the area had been diked. It must be noted that the total alkali content increased sharply (up to 0.93-4.15 g/l) and the absolute and relative content of SO_4 and Ca decreased to a certain extent as a result of their translation to the solid phase in the form of

gypsum and carbonates.

The high indices of general alkalinity suggest the presence of bicarbonates in the ground water, as well as alkali carbonates, such as sodium, which was found by us under analogous conditions in other diked areas.¹

Thus, as a result of the increased concentration of salts, a sodium bicarbonate stage of ground-water mineralization develops after diking in the zone of influence of the Akhtuba River (3).

By 1959 the mineralization of ground waters in the large oxbow lake increased to 33.76 g/l (borehole 23) as a result of the cessation of inundations and the evaporation of fresh surface waters, while in the non-irrigated northeastern part of the level area it increased to 29.45 g/l (Profile 5). The calcium-sodium-sulfate-chloride and sodium-chloride salinization of ground waters in sloughs and oxbow lakes was replaced thereby by chloride-calcium-magnesium and chloride-magnesium-calcium salinization, respectively. At the periphery of the oxbow lakes, where earlier mineralized ground water rose to

¹ According to our investigations, sodium is also found in the ground waters of the central flood plain in the Volga-Akhtuba flood plain, the mineral content of which varies from 0.5-3 g/liter.

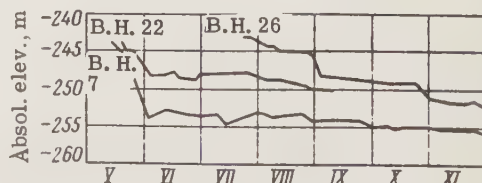


Fig. 3. - Curves of the changes in the surface ground-water level in a slough (borehole 7) and in an oxbow lake (boreholes 22, 25) as a result of the erection of the dike in the area, May-November 1953 (according to I.I. Tikhomirov).

the surface, its mineralization decreased (by 9.02-8.59 g/l) a result both of the precipitation of calcium and magnesium sulfates (borehole 21, Profile 6), and the displacement of the highest concentration of solutions toward the center of the lakes after inundations ceased.

There were no significant changes in the salinization of ground waters in areas which had been irrigated for three years (Profiles 1, 8). A certain increase of Ca, Mg and SO_4 ions in the composition of ground waters may be explained by their addition in the irrigated soil.

The soils in the diked area underwent the following changes. Before the area was diked, soils were represented by dark solonetzic solonchak-like fine clay loam flood-plain meadow soils in the level area; non-saline and solonchak-like gleyey, fine clay loam flood-plain wet meadow soils (stratified)² in the sloughs and oxbow lakes; and predominantly alluvial-meadow sandy loam and coarse clay loam flood-plain soils near the river. The central part of an oxbow lake located in the southeastern corner of the embanked area was occupied by moist meadow solonchak (8). As a result of the dike the dark solonetzic solonchak-like fine clay loam flood-plain meadow soils in the non-irrigated northeastern part of the area changed into dark solonetzic solonchak-like steppe-like flood-plain meadow soils. The non-saline and solonchak-like gleyey fine clay loam flood-plain wet meadow (stratified) soils of the sloughs and oxbow lakes changed into strongly solonchak-like gleyey wet meadow soils and wet meadow solonchaks. The alluvial-meadow sandy loam and coarse clay loam flood-plain soils in the area of influence of the Akhtuba River did not undergo any changes after the area had been diked.

The salt regime of the soils before the dike was constructed could be classified as of the seasonally reversible type (2), since annual floods contributed to the elimination of the seasonal salinization of soils. As a result of the dike and the cessation of floods, the seasonally-reversible type of salt processes was replaced by the seasonally-irreversible type, which led to an increase in the general salinization of soils.

A comparison of salt surveys (Fig. 4) made in October 1951 (9) and 1958 shows that the area of non-saline and weakly saline soils (Cl^- up to 0.04%) decreased from 73% to 50%, while the area of moderately saline soils (with a Cl^- content of 0.04%-0.1%) increased from 9%-19% and that occupied by solonchaks (Cl^- more than 0.2%) increased from 8%-20%. Below are given data characterizing the changes of salt contact in soil in the five years after the area had been diked.

Before the dike was built, dark solonetzic solonchak-like fine clay loam flood-plain meadow soils formed under conditions of annual flooding and capillary-ground water wetting. On November 5, 1950, they had the ground water at a

depth of 2.5 m. The quantity of water-soluble salts in the upper horizons of these soils to a depth of 40 cm did not exceed 0.25% (Table 2, Profile 5) on November 5, 1950 (8). The maximum salt content (0.93%) was found in the upper part of the zone wetted by capillary and ground water at a depth of 70 cm. With the proximity to the ground-water table the amount of solid residue decreased to 0.31% in the layer at a depth from 180-200 cm. Salinization of the layer at a depth of 60-70 cm was of the chloride-sulfate-magnesium-calcium type. The lower portion of the soil profile from a depth of 1 m had the chloride-sodium type of salinization. The ground water under dark solonetzic solonchak-like flood-plain meadow soils was mineralized (17.94 g/l) and belonged to the chloride-calcium-sodium type.

After the dike had been built, the dark solonetzic solonchak-like fine clay loam flood-plain meadow soils began to change into a dark steppe-like solonetzic strongly solonchak-like fine clay loam flood-plain meadow soils. The fall of the

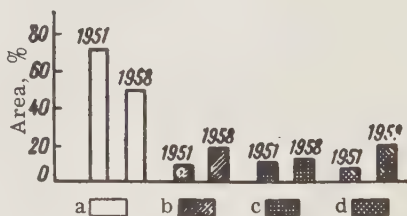


Fig. 4.- Changes in the areas occupied by saline soils (according to their chloride ion content in the upper 1 m, %) as a result of the dike for the period from October 1951-October 1958.

a - Cl^- up to 0.04%; b - Cl^- from 0.04%-0.1%; c - Cl^- from 0.1%-0.2%; d - Cl^- of more than 0.2%.

ground-water table under them (down to 3.8 m) promoted the transition from the capillary-ground water type of wetting to the film-capillary type of wetting.

The analysis of water extracts from the previous soil (Table 2, Profile 5) shows that five years after the dike was built (on September 25, 1958) the amount of solid residue in samples taken at depths of 30-40, 60-70 and 100-110 cm increased to 0.22%, 0.30%, respectively, even though the ground-water table fell 1.3 m. The increase in the salinized layer at a depth from 30-40 cm is, in our opinion, a result of the migration of salts from the lower layers toward the surface by film-capillary-diffusion flow. Total alkalinity along the profile decreased to 0.07%-0.021%. No change in the salinization of the layer at a depth from 60-70 cm occurred during this period. At a depth from 100-160 cm, chloride-sodium salinization was replaced by chloride-sulfate-calcium-sodium salinization. Any change in the type of salt in 60-70 cm layer did not occur at 100-160 cm depth. The chloride-sodium salt changed to chloride-sulfate-calcium-sodium. The gypsum content in samples taken from depths of 60-70 and 100-110 cm increased from 0.47%-4.31% and from 0.06%-3.73%, respec-

²Gleyey flood-plain wet meadow soils were formerly called flood-plain estuarine (5) and oxbow-lake meadow (1) soils.

Table 2

Analysis of the water extracts and the gypsum in soils of the diked area of Akhtuba sovkhos, % of absolutely dry soil

Profile Number	Depth, cm	Solid resi- due	Alkalinity		Cl	SO ₄	Ca	Mg	K+N by dif- ference	CaSO ₄ · 2H ₂ O
			Co ₂	HCO ₃						
5	Dark solonetzic solonchak-like fine clay loam flood-plain meadow soil, November 5, 1950									
	0—10	0,07	None	0,027	0,005	0,008	0,008	0,002	0,003	Not
	10—19	0,08	—	0,033	0,006	0,004	0,010	0,003	0,003	det'd.
	30—40	0,25	—	0,031	0,009	0,114	0,030	0,014	None	0,19
	60—70	0,93	—	0,047	0,113	0,449	0,081	0,036	0,120	0,47
	100—110	0,52	—	0,044	0,167	0,105	0,010	0,007	0,141	0,06
	130—150	0,50	—	0,044	0,173	0,104	0,016	0,008	0,140	0,11
	150—160	0,42	—	0,044	0,133	0,074	0,014	0,007	0,100	0,04
	180—200	0,31	—	Not det'd.	0,080					
								Not det'd.		
5	Dark steppe-like solonetzic strongly solonchak-like fine clay loam flood-plain meadow soil, September 25, 1958									
	0—10	0,09	None	0,026	0,012	0,030	0,002	0,002	0,025	0,15
	10—19	0,11	—	0,025	0,027	0,034	0,010	0,001	0,029	0,14
	30—40	0,54	—	0,024	0,220	0,121	0,054	0,015	0,119	0,14
	60—70	1,74	—	0,018	0,304	0,915	0,444	0,068	0,001	4,31
	100—110	1,90	—	0,023	0,335	0,925	0,464	0,070	0,002	3,73
	130—140	0,33	—	0,025	0,109	0,097	0,046	0,010	0,055	0,01
	150—160	0,24	—	0,032	0,070	0,073	0,020	0,002	0,064	0,08
	160—180	0,24	—	0,029	0,042	0,103	0,028	0,003	0,048	
	180—200	0,24	—	0,031	0,036	0,148	0,044	0,005	0,046	—
	200—300	0,82	—	0,023	0,340	0,185	0,128	0,027	0,119	—
	300—380	0,68	—	0,026	0,357	0,061	0,076	0,020	0,140	—
	450—580	0,46	—	0,023	0,248	0,035	0,080	0,012	0,071	—
20	Gleyey clay-fine clay loam flood-plain wet meadow (stratified) soil, May 3, 1953									
	0—20	0,16	None	0,032	0,032	0,008	0,010	0,003	0,01	Not
	60—80	0,13	None	0,031	0,031	0,030	0,007	0,003	0,03	det'd.
20	Gleyey strongly solonchak-like clay-fine clay loam flood-plain moist meadow (stratified) soil, April 27, 1959									
	0—20	0,27	None	0,050	0,122	0,039	0,062	0,023	0,002	
	25—50	1,10	None	0,024	0,672	0,022	0,124	0,061	0,197	Not
	60—80	0,91	None	0,035	0,494	0,066	0,162	0,015	0,150	det'd.
	100—150	0,76	None	0,024	0,440	0,022	0,057	0,026	0,189	"
25	Gleyey solonchak-like clay loam flood-plain wet meadow (stratified) soil, May 3, 1953									
	0—20	0,24	None	0,021	0,040	0,075	0,034	0,010	0,010	—
	50—60	0,92	None	0,023	0,129	0,481	0,145	0,032	0,092	—
25	Gleyey strongly solonchak-like clay loam flood-plain wet meadow (stratified) soil, April 27, 1959									
	0—20	0,53	None	0,063	0,213	0,070	0,058	0,015	0,139	—
	50—60	0,94	None	0,031	0,498	0,023	0,051	0,038	0,213	—
10	Dark strongly solonchak-like fine clay loam flood-plain meadow soil, May 3, 1953									
	0—20	1,11	None	0,031	0,224	0,478	0,166	0,037	0,124	—
	30—90	1,94	None	0,031	0,396	0,766	0,258	0,056	0,232	—
10	Dark solonchak-like fine clay loam flood-plain meadow soil, September 25, 1958									
	0—20	0,99	None	0,064	0,005	0,654	0,222	0,043	0,004	—
	30—90	0,84	None	0,080	0,126	0,425	0,166	0,048	0,033	—

Note: Comma represents decimal point.

VOLGA-AKHTUBA FLOOD PLAIN

Table 2 (continuation)

Profile Number	Depth, cm	Solid residue	Alkalinity		Cl	SO ₄	Ca	Mg	K+Na by difference	CaSO ₄ ·2H ₂ O
			CO ₃	HCO ₃						
3	Alluvial-meadow coarse clay loam flood-plain soil, September 25, 1958									
	0—25	0,14	None	0,033	0,010	0,057	0,014	0,006	0,020	—
	25—50	0,09	None	0,033	0,010	0,023	0,009	0,008	0,004	—
	50—100	0,14	None	0,024	0,010	0,080	0,009	0,006	0,009	—
	100—150	0,13	None	0,024	0,010	0,057	0,005	0,006	0,026	—
	150—200	0,16	None	0,050	0,010	0,057	0,005	0,036	0,033	—

Note: Comma represents decimal point.

ively. Because of the lowering of the ground-water table, the present horizon of salt accumulation moved to a depth of 200-380 cm. Salinization at a depth from 200-300 cm assumed a chloride-magnesium-calcium type, while at a depth from 300-380 cm is assumed a chloride-calcium-sodium type.

Because the soil became more steppe-like the amount of humus in the layer from the surface down to 10 cm decreased from 2.63% to 1.45%, while in the layer from 10-19 cm it decreased from 1.45% to 1.35% (Table 3).

The amount of solid residue in samples taken on May 3, 1953 (10), at depth from 0-20 and 60-80 cm from the gleyey clay fine clay loam flood-plain wet meadow (stratified) soil of a slough (borehole 20) was 0.16% and 0.13%, respectively. The mineralization of the ground water found at a depth of 120 cm was 4.7 g/l and belonged to the chloride-sodium type.

After the area had been diked, the gleyey clay fine clay loam flood-plain wet meadow soils began to change into gleyey strongly solonchak-like clay fine clay loam wet meadow soils. The ground-water table under them dropped to 80 cm and its mineralization increased to 25.6 g/l, as recorded on September 1, 1953 (10). The sharp increase in the mineralization of the ground water may be explained by the evaporation of the upper fresh surface water and the intrusion into the capillary fringe of the soils of

the main flow of mineralized waters. The solid residue of soil samples taken at depths from 0-20 and 60-80 cm increased thereby from 0.16% to 0.27% and from 0.13% to 0.91%, respectively. The amount of chloride ions increased from 0.03% to 0.12% and even to 0.49%.

The highest salinization (1.10%) and the highest chloride ion content (0.67%) are now found in the zone of capillary-ground water wetting in the depth interval from 25-50 cm. The increase in total alkalinity in the layer from 0-20 cm to 0.05% indicates a certain solonetzation of this layer in the process of the periodic desalinization of the upper horizons by local flow of waters. On the whole, salinization of the soils took on a chloride-magnesium-calcium nature.

A similar picture is observed in the large oxbow lake adjoining the main shore. Here, gleyey solonchak-like clay loam flood-plain wet meadow (stratified) soils changed into gleyey strongly solonchak-like clay loam flood-plain wet meadow (stratified) soils as a result of diking and of the lowering of the ground-water table. The amount of chloride ions during this period increased in these soils from 0.04%-0.21% at a depth from 0-20 cm, and from 0.12%-0.49% at a depth from 50-60 cm (Table 2, borehole 25).

The nature of the change in soil processes in irrigated soils was different. For instance, the chloride ion content in the dark, strongly solon-

Table 3

Change in the humus and nitrogen content of dark solonchak-like fine clay loam flood-plain meadow soil as a result of it becoming more steppe-like (Profile 5)

Depth, cm	Humus, % (according to Tyurin)		Total nitrogen content, % (by Kjeldahl method)	
	Nov. 5, 1950	Nov. 25, 1958	Nov. 5, 1950	Nov. 25, 1958
0-10	2,63	2,08	0,12	0,10
10-19	1,45	1,35	0,08	0,07
30-40	1,42	1,11	0,06	0,05

Note: Comma represents decimal point.

chak-like flood-plain meadow soil samples taken from depths of 0-20 cm and 30-90 cm decreased considerably (Table 2, Profile 10). The observed increase in total alkalinity (HCO_3^-) may be explained by the dilution of soil solutions (2) and a certain solonetzation of soils during their desalinization.

Analysis of water extracts from the alluvial-meadow soil in the zone of influence of the Akhtub River (Table 2, Profile 3) indicates that this soil is not salinized, both as far as the amount of solid residue and the chloride ion content are concerned. No noticeable displacement of the chloride ion along the profile of this soil was observed. A slight increase in total alkalinity in the layer from 150-200 cm permits us to assume that a certain solonetzation occurred at depth at the expense of the alkalinity of ground waters.

Conclusions

1. In the diked area of the Akhtub sovkhos the ground-water table dropped in the level area, except in that under the influence of the Akhtub River, an average of 1 m and in the sloughs and oxbow lakes, 1.5 m, five years after the area had been diked.

Because inundations ceased, the leaching regime was replaced by seepage which led to the progressive salinization of soils in the area, fed by mineralized ground waters. Five years after the dike was built, the area occupied by non-saline and weakly saline soils (according to the chloride ion content) decreased by 23% and the area occupied by moderately saline and solonchak soils increased correspondingly by 10% and 12%.

2. With the change in hydrological and hydrogeological conditions, meadow vegetation in the nonirrigated level area was displaced by steppe and halophytic vegetation. Dark solonchak-like flood-plain meadow soils began to dry up and become more steppe-like, which was accompanied by a deterioration of their structure, mineralization of humus and salinization.

After the fresh surface waters evaporated, gleyey non-saline and solonchak-like flood-plain wet meadow (stratified) soils in the sloughs and oxbow lakes came under the influence of mineralized ground waters derived from saline deposits in the main shore, and changed into gleyey strongly solonchak-like flood-plain wet meadow soils and wet meadow solonchak.

3. In irrigated areas, where the leaching regime was artificially sustained, desalinization of soils occurred.

4. Alluvial-meadow soils along the river did not undergo any change after the dike had been built because of the fresh water from the Akhtub River.

5. Since a drainage and collecting system for the interception of mineralized ground water derived from the main shore and the diversion of leaching water into the diked areas cannot be constructed because of the presence of sand of

the quicksand type and the absence of impermeable horizons, the salinized soils must be meliorated by water supply irrigation in autumn.

To prevent surface salinization during the irrigation of solonchak-like soils, moisture must be sustained at a level of not less than 70% of the field capacity.

6. The reclamation of gleyey strongly solonchak-like wet meadow soils, fed by highly mineralized ground waters from the main shore, require leaching.

Received December 30, 1959

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INCREASING THE EFFECTIVENESS OF THE RESIDUAL EFFECT OF PHOSPHOROUS FERTILIZERS

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From the experience gained in the use of phosphorous fertilizers, it is known that the coefficient of phosphorous utilization from these fertilizers (under the existing conditions of use) is considerably lower than the coefficient of nitrogen and potassium utilization.

The primary cause of the lower availability of phosphorus to plants is believed to be its property of producing compounds of phosphoric acids insoluble in water on interaction with the soil, whereby it loses its mobility in the soil and the ability to move with the soil solution toward the roots of plants. This was clearly formulated by Sokolov (8), who pointed to the fact that the differential utilization of various types of fertilizers by plants is associated with the nature of their distribution in the soil. Nitrates, which are most evenly distributed in the soil and rapidly move with soil moisture, are best utilized by plants (70%-80%). Potassium is less well utilized (30%-70%), since it is less mobile than nitrate nitrogen, and consequently is less evenly distributed in the soil. Phosphorus, applied to the soil with fertilizers, becomes unevenly distributed (in spots) so that not all root hairs come in contact with it, and, consequently, is even less utilized by plants (10%-20%).

Taking this into account, phosphorous fertilizers are applied in excess, in amounts equal to nitrogen or even more, in spite of the fact that the requirement of plants for phosphorus is three times less than the requirement for nitrogen.

Recently, fagged elements have shown the slight utilization of phosphorous fertilizers by plants and should be studied in more detail.

Formerly, the uptake of phosphorus by plants from fertilizers was determined from the difference between the removal of phosphorus by fertilized and non-fertilized plants, whereby it was assumed that the soil phosphates are utilized by plants in the same way in fertilized and non-fertilized plots. This assumption was recently disproved (9) and it was shown that the determination of removed phosphorus by means of tagged fertilizers gives different results in a series of cases than determination by the so-called "difference" method. However, the results of these investigations have generally not changed the prevailing opinion that the coef-

ficient of utilization of phosphorus from fertilizers is lower than that of nitrogen and potassium.

In many cases residual phosphorus is poorly utilized. This has been explained in different ways. It was assumed that the decrease of the effectiveness of residual phosphorous fertilizers is associated with processes of irreversible uptake and the fixation of phosphorus in the soil, which, presumably, increase with the increase in the duration of the interaction between phosphorus and soil. This assumption was not substantiated by the experiments of many investigators on various soils, including our own experiments (1).

According to another opinion, which was first voiced by Naydin (7), and developed by Chirikov (12), the low residual effect of phosphorus in a series of experiments is due to the shortage of nitrogen, or nitrogen and potassium, for plants.

The results of our pot experiments in preceding years (2) showed that the interaction between phosphorus and chernozem and soils related to it by their properties had an insignificant effect on the solubility and availability of phosphorus to plants within a period of a year and a half. It was shown that the observed absence of a residual effect on following crops is to be attributed to the improper relationship between the major nutrients required by plants and not to the "retrogradation" of phosphorus as formerly thought. Such a disparity is governed by an excess of phosphorus in soil, which is only partly used by the first crop, and the shortage of nitrogen and potassium, which are almost completely taken up by it.

In extending our investigations on the subject, we made pot and field experiments with various crops on various soils, in which we studied the effectiveness of the residual effect of phosphorous fertilizers during their prolonged interaction with soil. The period, this time, was years and not months. For this, the permanent field experiments of a number of experimental stations in various areas of the Ukrainian SSR were used.

Pot experiments were made on soils selected on the basis of permanent experiments at five experimental institutions, from plots both fertilized and not fertilized with phosphorus in the past.

The following soils were tested in the spring

PHOSPHOROUS FERTILIZERS

Table 1

Content of various forms of phosphorus in soils taken for pot experiments

Soil	Extract								
	Carbon dioxide			Acetic acid			Hydrochloric acid		
	Phosphorous content in mg P ₂ O ₅ per 100 g of soil in various experimental plots								
	O	P	PNK	O	P	PNK	O	P	PNK
Thick chernozem with a low humus content, Drabovo	1,0	2,9	3,2	10,3	17,5	18,9	12,8	19,1	19,7
Same, Mironovka	1,0	2,9	3,9	10,3	18,6	20,0	19,8	37,4	40,1
Same, Sumy	2,8	—	3,3	16,3	—	18,9	31,4	—	33,3
Meadow-chernozem, near Kiev	0,6	1,0	1,5	5,1	7,7	11,7	9,5	12,9	19,2
Dark-gray forest soil, Chartoriya	1,1	1,3	2,8	8,8	9,7	10,5	16,7	17,3	19,8

Note: Comma represents decimal point.

of 1958.

1. Three treatments of thick, weakly podzolized chernozem with a low humus content, taken from the Drabovo experimental field in the Cherkasy Region. The first treatment was not fertilized; the second was fertilized only with superphosphate at a rate of 270 kg/ha P_2O_5 ; and in the third superphosphate at a rate of 380 kg/ha P_2O_5 was applied together with nitrogen and potassium fertilizers in a N:P:K ratio of 1:1.9:1.3. The fertilizers were applied during a period of seven years, starting in 1949.

2. Three treatments of thick, slightly leached chernozem with a low humus content, taken from the Mironovka experimental station, in which one was not fertilized since 1929. The second was fertilized with superphosphate only at a rate of 170 kg/ha P_2O_5 ; and the third was fertilized with superphosphate at a rate of 340 kg/ha P_2O_5 together with nitrogen and potassium fertilizers in a N:P:K ratio of 1:1.5:1.5. The last time, fertilizers were applied under sugar beet in 1956.

3. Two treatments of thick, slightly leached chernozem with a low humus content, taken from the Sumy State Agricultural Experimental station. The first was not fertilized with phosphorus, and the second was fertilized for four years (1954-1957) with 180 kg/ha P_2O_5 together with nitrogen and potassium fertilizers in a N:P:K ratio of 1:1.8:1.5.

4. Three treatments of podzolized meadow-chernozem taken from the experimental station of the Ukrainian Scientific Research Institute of Plant Physiology, near Kiev. The first was not fertilized with phosphorus; the second was fertilized once in 1952 with superphosphate at a rate of 240 kg/ha P_2O_5 ; and the third was fertilized the same year with ground rock phosphate at a rate of 480 kg/ha P_2O_5 .

5. Three treatments of gray podzolized forest soil from the Chartoriya experimental field

in Zhitomir Region. One was not fertilized with phosphorus; the other two were fertilized for four years, up until and including 1956. One of these was fertilized with 125 kg/ha P_2O_5 in the form of superphosphate and the other with 200 kg/ha P_2O_5 , also in the form of superphosphate, but together with nitrogen and potassium fertilizers in a N:P:K ratio of 1:1.1:1.1.

In spite of the fact that the crops in permanent experiments took up much phosphorous fertilizer, a lot of it was left in the soil in a more or less mobile form when the pot experiments were started, as can be seen from the results of soil phosphate determinations made by the method of Chirikov (11) (Table 1). All phosphate-fertilized soil samples, selected for permanent experimental plots, contained more phosphorus which had entered into carbon dioxide, acetic acid and hydrochloric acid extracts than samples from non-fertilized plots. These data point to the fact that the phosphorus from the fertilizers was not fully utilized by experimental crops under rotation.

The program of pot experiments provided for the study of the effect of nitrogen and potassium fertilizers on the utilization of phosphate fertilizers, which were used in the previously mentioned five permanent field experiments. For this purpose one series of pots in each treatment of the experiments (without fertilizer, with phosphorus, and with phosphorus and potassium and nitrogen) was left without nitrogen and potassium, while nitrogen and potassium were applied to another series of pots. Nitrogen was applied at a rate of 100 mg/km of soil in the form of ammonium nitrate and potassium was applied at a rate of 70 kg (K_2O) in the form of potassium chloride. The experiments were made in glass vessels (containing 7 kg of soil) with oats in 1958 and with millet to which nitrogen and potassium were applied (in the same vessels in which these elements were applied to oat) in 1959.

The results of the experiments are given in

Table 2

Residual effect of phosphorous fertilizers under the influence of additional applications of nitrogen and potassium fertilizers in pot experiments, yield in grams per pot

Soil and location	Fertilizers applied in the field									
	Without fertilizer				Phosphorus				Phosphorus, nitrogen and potassium	
	Total		Grain		Total		Grain		Total	Grain
	yield with out NK	addition of NK	yield with out NK	addition of NK	yield with out NK	addition of NK	yield with out NK	addition of NK	yield with out NK	addition of NK
Experiment with oat, 1958										
Thick chernozem with a low humus content, Drabovo	11,6	14,9	4,3	5,2	13,4	20,1	4,5	5,9	17,8	20,8
Thick chernozem with a low humus content, Mironovka	7,4	18,4	2,16	4,9	9,6	23,3	2,8	7,4	12,6	21,9
Thick chernozem with a low humus content, Sumy	9,9	13,3	4,16	4,0	—	—	—	—	11,0	17,2
Meadow-chernozem soil, near Kiev	6,8	13,2	2,5	4,2	12,2	18,3	4,9	5,7	12,2	17,5
Dark-gray forest soil, Chartoriya	11,6	11,1	3,9	3,2	12,5	14,8	5,4	3,8	11,9	12,8
Experiment with millet after oat, 1959										
Thick chernozem with a low humus content, Drabovo	10,0	10,0	4,4	6,7	8,6	29,0	3,7	15,0	10,8	33,0
Thick chernozem with a low humus content, Mironovka	8,8	19,4	4,1	9,6	8,1	25,0	3,5	13,6	10,6	32,4
Thick chernozem with a low humus content, Sumy	9,4	18,4	4,6	10,1	—	—	—	—	6,5	20,1
Meadow-chernozem soil, near Kiev	9,8	11,5	4,9	4,8	9,6	28,0	4,5	16,2	8,7	25,9
Dark-gray forest soil, Chartoriya	9,5	18,7	4,7	10,3	10,0	21,7	4,4	11,7	9,3	23,9

Note: Instead of N, P and K, only P (480 kg/ha P_2O_5 in the form of rock phosphate) was applied to the meadow-chernozem soil in the field.

Note: Comma represents decimal point.

Table 2. They show that without nitrogen and potassium, the residual effect of phosphorous is very small. The magnitude of the residual effect may be judged by the difference between the yield in pots filled with soil from the experimental plot fertilized with phosphorous and that in pots filled with soil which was not fertilized in the field. Such calculations show that in the experiment with oats the increase in total yield as a result of residual effect of phosphorous varied from 0.9-2.2 gm per vessel in four of the five soils, depending on soil and other experimental conditions, and only in one vessel did it exceed this value. In the experiment with millet the residual effect of phosphorous was absent without the application of nitrogen and potassium in all cases without exception.

The residual effect of phosphorous, applied singly or together with nitrogen and potassium fertilizers in the field, on the yield of oats and millet increases considerably when nitrogen and potassium are applied in the pots. An idea of

the increment of yield owing to the residual effect of phosphorous on the background of nitrogen and potassium, applied in the vessels, may be obtained from the difference between the increase in yield from nitrogen and potassium on soils fertilized with phosphorous in the field and the increase in yield from these elements on soil not fertilized with phosphorous. In the oat experiment, the highest increase in total yield from residual effect of phosphorous (5.2 gm per vessel) occurred on the thick chernozem with a low humus content from Drabovo and the least (3.7 gm per vessel), on the gray forest soil from the Chartoriya experimental field.

The effectiveness of the residual effect of phosphorous on the background of nitrogen and potassium was even higher in the millet experiment. Here the highest increase in yield from the residual effect of phosphorous occurred (as in the oat experiment) on the thick chernozem with a low humus content from the Drabovo experimental field (18.3 gm per vessel), and the

PHOSPHOROUS FERTILIZERS

Table 3

Influence of nitrogen fertilizers on the residual effect of the phosphorous fertilizer. Field experiments on meadow-chernozem soil under oats and sugar beets, 1958

Experimental indices	Fertilizers used in the past			
	without fertilizer		phosphorus	
	oats	sugar beets	oats	sugar beets
Phosphorous content, mg P_2O_5 per 100 g of soil				
Acetic acid extract	5,9	8,8	10,4	9,7
Hydrochloric acid extract	14,4	16,7	29,4	19,8
Yield of oat grain and beet roots, cntr/ha				
Without nitrogen	23,7	212,9	24,9	309,8
Increment from nitrogen application	1,9	40,6	4,1	75,7

Note: Comma represents decimal point.

lowest (3.0 gm per vessel) on the dark-gray forest soil from the Chartoriya experimental field. The same marked efficacy of the residual effect in increasing the yield of oat and millet was also observed for phosphorus applied in the field together with nitrogen and potassium fertilizers (data in the last four columns of Table 2).

During short-term field experiments in 1958 we studied the direct effect of the nitrogen fertilizer on the yield of oat and sugar beet.

The oat experiment was made at a station site established at one time by A. V. Lazurskiy on the meadow-chernozem soil of the experi-

mental station of the Ukrainian Scientific Research Institute of Plant Physiology. The experiment was made on two sites, one of which was not fertilized while the other was fertilized in 1954 with superphosphate at a rate of 240 kg/ha P_2O_5 . Before the experiments were made the sites (100 m² each) were divided in two, and one half was fertilized with nitrogen at a rate of 60 kg/ha by turning it in before sowing, and the other was not fertilized. The experiment was replicated four times.

The same method was used in making short-term experiments with sugar beet at a station on the gray forest soil of the Chartoriya experimental field. The experiment was made on non-fertilized soil and soil fertilized with superphosphate at a rate of 125 kg/ha P_2O_5 for the last five years.

The results of phosphorous determinations in the soil by the method of Chirikov, as well as yield data are presented in Table 3. These data show that the application of nitrogen considerably increases the residual effect of phosphorus, as seen from the increment in yield from nitrogen on plots fertilized and not fertilized with phosphorus. It is clear that the higher increments in the yield of oats and sugar beets from the application of nitrogen on plots fertilized with phosphorus, as compared to the increment on non-fertilized plots, result from the residual effect of phosphorous fertilizers.

The same is true of the residual effect of phosphorus in the corn experiment made in 1959 at the same experimental station of the Ukrainian Scientific Research Institute of Plant Physiology, where the oat experiment was made in 1958, except that the site was located on the other side of the field. The corn experiment was made after winter wheat was harvested on three sites: 1) non-fertilized; 2) fertilized with superphosphate at a rate of 240 kg/ha P_2O_5 ; and 3) fertilized with ground rock phosphate at a rate of 480 kg/ha P_2O_5 . Phosphorus was applied two times in equal amounts, in 1950 and in 1954.

The experimental method was the same as

Table 4

Influence of nitrogen and potassium fertilizers on the residual effect of phosphorous fertilizers. Field experiment with corn, 1959. Yield in cntr/ha.

Fertilizer applied in the past (kg/ha P_2O_5)	Yield of total shoot		Yield of corn cob			
			Total		Including normally developed	
	without nitro. and potassium	with nitro. and potassium	without nitro. and potassium	with nitro. and potassium	without nitro. and potassium	with nitro. and potassium
Without fertilization	270,7	0,4	71,7	2,8	55,4	4,1
Ps ^a 240	290,8	24,8	82,9	8,8	69,7	7,8
Pr 480	262,5	29,0	70,3	19,4	57,4	17,4

^aPs — superphosphate; Pr — rock phosphate.

Note: Comma represents decimal point.

that used in the experiment with oats and sugar beets. The only difference was that in addition to nitrogen, potassium was also applied. The results of this experiment, which are presented in Table 4, indicate that here also the residual effect of phosphates was sharply enhanced by nitrogen and potassium. Indications of the positive influence of nitrogen and combined nitrogen and potassium fertilizers on the efficacy of the residual effect of phosphorous fertilizers may be found in the works of many investigators in the Soviet Union as well as abroad, who conducted their experiments under conditions differing from ours (3, 5, 6, 10, 13, 14, 15).

The nature of the effect and residual effect of superphosphate, applied singly and in combination with nitrogen and potassium fertilizers in an experiment over 29 years (1930-1958) exclusively with corn on the thick, slightly leached chernozem with a low humus content of the Mironovka experimental station (5), must be especially noted.

In this experiment no decrease in corn yield was observed on the non-fertilized plot in the 29th year after the experiment was started. The sharp decrease in yield (2.4 times) under the influence of annual (during 29 years) applications of superphosphate, was considerably reduced by an application of a combination of superphosphate and potassium and nitrogen fertilizers. When these fertilizers were applied in a N:P:K ratio of 1:1:1, yield was only 1.8 times lower than normal and not 2.4 times lower as before when only phosphorus was used. When the fertilizers were applied in spring in a N:P:K ratio of 2:1:2, yield was reduced only 1.2 times. The results of this experiment indicate how important the correct ratio of nutrients is for increasing yield and for the optimum utilization of fertilizers.

In conclusion we must mention an original idea voiced at one time by Kostychev (4) about the effective use of phosphorous fertilizers, since it has a direct bearing on the results of the experiments described in this article. This idea was expressed in the following words "... phosphates are one-sided fertilizers so that they can be used singly with optimum effectiveness only in rare cases. In general, however, they are much better used in combination with other fertilizers, since they then reinforced the effect of each other."

The experiments described show that in order to use phosphorous fertilizers effectively in crop rotation and increase the yield not only of the crop for which they are used, but of following crops, it is not sufficient to apply them in combination with nitrogen and potassium fertilizers. Additional applications of nitrogen or a combination of nitrogen and potassium fertilizers must be made to increase the efficacy of the residual effect of phosphorous fertilizers, since nitrogen and potassium are better utilized than phosphorus.

Received October 22, 1959

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INFLUENCE OF POTASSIUM FERTILIZERS ON THE YIELD OF HAY AND ALFALFA ROOTS ON MEADOW SOILS IN THE IRRIGATED ZONE OF CENTRAL ASIA

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The exceptional role played by alfalfa in cattle feed and in the improvement of the soil fertility in the irrigated zone of Central Asia, and the problem of the use of fertilizers, especially potassium (for alfalfa has been studied little), led us to conduct experiments from 1956-1958 on the optimum time of application and amount of potassium fertilizers. The experiments were made on the meadow soil of the experimental farm of the Agricultural Institute of Tashkent during the spring and autumn sowing of alfalfa.

In the first experiment alfalfa was sown on July 26, 1955, and in the second on April 4, 1956. The seeds used were of the Peruvian 3192 variety. They were sown with an STZ-19 horse-drawn seeder at a rate of 16 kg/ha. The crops preceding alfalfa were not fertilized and included potato in 1954 and early onion in 1955. The experiments were replicated four times. The size of the plots was 150 m² in the first experiment and 125 m² in the second.

Potassium fertilizer was applied in the form of potassium chloride containing 54% of potassium oxide and phosphorous fertilizer was applied in the form of 18% superphosphate. The fertilizers were evenly spread at the surface in the fall and plowed under to a depth of 25 cm.

Both experiments were made side by side on one area, the characteristics of which are given in Table 1.

As can be seen from the data, the soil of the experimental area is moderately provided with humus, available forms of phosphorus and potassium.

In the first experiment alfalfa was irrigated twice before wintering, on August 29 and on October 6, 1955. The first year alfalfa was cut four times and irrigated four times, the second year it was cut five times and irrigated five times, and in the third year it was cut four times and irrigated four times. In the second experiment alfalfa was cut three times and irrigated four times in the first year, and cut four times and irrigated four times in the second and third years. The experimental setup is shown in Table 2. Data on the yield of orange alfalfa during a period of three years are given in Tables 3 and 4. A comparison of these data shows that the yield of alfalfa hay is considerably higher for fall sowing than for

spring sowing and that the effectiveness of fertilizers is also somewhat higher for alfalfa sown in the fall. This is why we consider that fall sowing of alfalfa is best.

As the results of the experiments show, potassium fertilizers are sufficiently effective. A definite increase in yield from the fertilizer is noted the first year after sowing and the year after. The third year after sowing, however, the effect of the fertilizer decreases sharply.

Data of both experiments show the effectiveness of an addition of potassium in the form of a second application of a small amount during harrowing immediately before sowing after the initial amount of 90 kg/ha was applied during the major plowing (treatment 7). These data also indicate the effectiveness of an application of potassium and phosphorous fertilizers the second year after sowing (treatments 8 and 9).

The data obtained on the yield of alfalfa the first and second year after sowing were analyzed mathematically (Tables 3 and 4). As may be seen, the increase in yield from potassium fertilizers in treatments 4, 5, 6, 7 and 9 of both experiments is reliable. The yield of 1958 was not subjected to mathematical analysis because the residual effect of the fertilizer decreased sharply.

In order to determine the effect of fertilizers on soil fertility, the root mass of alfalfa was measured at the end of the first and second years, assuming that the increase in the yield of tops must be accompanied by an increase in root mass.

The method used for measuring the roots consists of the following. Three areas with a typical stand of alfalfa were selected in each plot of the same crop after the last cutting. These areas were arranged diagonally in each plot. From these areas blocks of soil 50 x 50 cm and 40 cm deep were taken where the density of alfalfa was the same. The block with the roots was cut in two layers from 0-25 cm and from 25-40 cm and washed in bags first in running water (from an irrigation ditch) and then in tap water. After the roots were clean they were separated from weeds. Since the amount of weeds was insignificant, their weight was not taken into account. The alfalfa roots

Table 1

Chemical characteristics of soils used in the experiments

Depth, cm	Content, %			Content of phosphates extracted in 1% ammonium carbonate P_2O_5 mg/kg of soil	Total content of potassium, %	Available forms of potassium, mg/kg of soil	
	Humus	Nitrogen	Phosphorus			Exchangeable, extracted in an ammonium carbonate extract	Soluble in water
		Total					
0—25	2,46	0,118	0,162	44,7	1,97	52.3	10.7
25—40	2,03	0,082	0,152	22,3	1,85	45.6	8.0

Note: Comma represents decimal point.

Table 2

Experimental setup

Treatment No.	Annual rate kg/ha		Distribution of fertilizer application, kg/ha					
			Applied during main plowing		Harrowed in before sowing		Harrowed in the 2nd year	
	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
1	120	—	90	—	30	—	—	—
2	120	15	90	—	30	15	—	—
3	120	30	90	30	30	—	—	—
4	120	45	90	30	30	15	—	—
5	120	60	90	60	30	—	—	—
6	120	75	90	60	30	15	—	—
7	120	90	90	60	30	30	—	—
8	120	—	90	—	—	—	30	—
9	120	90	90	60	—	—	30	30

Table 3

Influence of potassium fertilizers on the yield of forage alfalfa the year fertilizers were applied and in the following two years, cntr/ha (first experiment with fall sowing)

Treatment No.	1956		1957		Results of mathematical analysis of mean data on yield from 1956-1957			1958		In three years		
	Yield	Increment	Yield	Increment				Yield	Increment	Yield	Increment	
					±m		D md				cntr/ ha	%
1	98,6	—	174,4	—	2,61	0,96	—	159,4	—	432,4	—	100
2	102,4	3,8	174,5	0,1	2,76	0,99	1,0	159,1	—0,3	436,0	3,6	100,5
3	102,3	3,7	177,4	3,0	2,51	0,89	1,9	159,2	—0,2	438,9	6,5	101,2
4	105,7	7,1	179,2	4,8	3,08	1,08	3,0	161,3	1,9	446,2	13,8	102,8
5	105,4	6,8	183,4	9,0	2,83	0,97	3,5	162,3	2,8	451,0	18,6	104,0
6	112,6	13,6	184,2	9,8	3,81	1,28	5,0	161,3	2,5	458,3	25,9	105,7
7	115,0	16,4	187,4	13,0	3,57	1,18	6,5	161,6	2,2	464,0	31,6	107,0
8	95,0	—3,6	176,6	2,2	1,76	0,64	—	157,2	—2,2	428,8	—3,6	94,3
9	103,1	4,5	183,3	8,9	2,30	0,81	3,8	157,5	—1,9	443,9	11,5	102,4

Note: Comma represents decimal point.

were assessed by size, whereby roots more than 1.5 mm in diameter were considered large, while those less than 1.5 mm in diameter were

considered small. The roots were then air-dried in a thermostat at 60°C for two days and then kept at room temperature for three days

POTASSIUM FERTILIZERS

Table 4

Influence of potassium fertilizers on the yield of forage alfalfa the year fertilizers were applied and in the following two years, cntr/ha (second experiment with fall sowing)

Treatment No.	1956		1957		Results of mathematical analysis of mean data on yield from 1956-1957			1958		In three years		
	Yield	Increment	Yield	Increment	$\pm m$		$\frac{D}{md}$	Yield	Increment	Yield	Increment	
											cntr/ha	%
1	69,5	—	136,8	—	2,00	0,97	—	134,6	—	340,9	—	100
2	71,8	2,3	136,3	—0,5	2,243	1,08	0,5	134,1	—0,5	342,2	1,3	100,3
3	71,9	2,4	139,8	3,0	2,929	1,38	1,5	134,8	0,2	346,5	5,6	101,6
4	73,6	4,1	144,3	7,5	1,229	0,56	4,8	135,7	1,1	353,6	12,7	103,7
5	73,8	4,3	145,7	8,9	2,191	0,99	4,4	136,9	2,3	356,4	15,5	104,5
6	76,3	7,8	146,9	10,1	1,975	0,88	6,0	136,2	1,6	360,4	19,5	105,7
7	79,9	10,4	150,2	13,4	2,544	1,11	7,3	136,5	1,9	366,5	25,7	107,4
8	67,3	—2,2	138,3	1,5	2,032	0,99	—	132,4	—2,2	338,0	—2,9	99,1
9	72,7	3,2	144,6	7,8	2,753	1,27	3,1	134,9	0,3	352,2	11,3	103,2

Note: Comma represents decimal point.

Table 5

Influence of potassium fertilizers in the year of application on the root mass of alfalfa; air-dried mass, cntr/ha

Treatment No.	Depth, cm				Total root mass in the layer from 0-40 cm	Increment	
	0-25		25-40			cntr/ ha	%
	Roots						
	Large	Small	Large	Small			
1	42,4	10,0	11,0	2,1	65,5	—	100
2	42,8	9,9	11,2	2,0	65,9	0,4	100
3	43,0	10,4	10,9	2,7	67,0	1,5	102,3
4	43,7	11,3	12,1	2,1	69,2	3,7	105,6
5	44,8	11,7	12,0	2,2	70,7	5,2	108,0
6	46,3	12,0	12,0	2,3	72,6	7,1	110,8
7	46,5	11,7	12,2	2,1	72,5	7,0	110,8
8	41,8	9,2	10,4	1,7	63,1	—2,4	96,3
9	45,5	10,2	11,7	2,2	69,6	4,1	106,2

Note: Comma represents decimal point.

The results of the root yields are given in tables 5 and 6.

A comparison of these data shows a considerable increase in the root yield the second year as compared to the first year. The positive influence of the fertilizer on the root yield is somewhat more pronounced the following year than the year the fertilizer was applied. As may be seen from the data, the yield of roots increased both the first and second year after the application of the potassium fertilizer, thereby an additional application of potassium was accompanied by an increase in root mass.

An analysis of the data indicates an increase in the relative effectiveness of fertilizers with an increase in their amount up to 90 kg/ha K_2O . Thus, proceeding from the data on the accumulation of the root mass the second year after sowing, and by comparing the various

amounts of potassium, we obtain the following picture. An application of 15 kg/ha K_2O (treatment 2) did not affect the yield of roots of two-year old alfalfa. A doubling of the amount of fertilizer (treatment 3) was accompanied by an increase in root yield of 2.8 cntr/ha. A further increase of the amount by 15 kg/ha K_2O (treatment 4) increased the yield by 1.1 cntr/ha. An increase of up to 60 kg/ha K_2O (treatment 5) gave rise to an additional increase in yield of 3.3 cntr/ha. Further increases in the amount of fertilizer, even though they increase the cost of the root harvest, are still profitable. An application of 90 kg/ha K_2O (treatment 7) is accompanied by an increase in the yield of air-dried roots of 9.3 cntr/ha.

Potassium fertilizers not only increase the yield of alfalfa hay, but also increase the fertility of fields. Let us note that the use of part of the total amount of phosphorus (treatment 8),

Table 6

Influence of potassium fertilizers on the accumulation of root mass of two-year old alfalfa; air-dried mass, cntr/ha

Treatment No.	Depth, cm				Total root mass in the layer 0-40 cm	Increment	
	0-25		25-40			cntr/ ha	%
	Roots						
	Large	Small	Large	Small			
1	63,6	14,4	15,2	4,0	96,9	—	100
2	62,8	13,9	15,7	4,3	96,7	—0,2	100
3	66,7	14,6	14,0	4,2	99,5	2,6	102,7
4	64,1	15,6	16,3	4,6	100,6	3,9	104,0
5	63,6	17,0	18,0	5,5	104,1	7,2	107,4
6	67,3	16,1	17,0	4,3	104,7	7,8	109,2
7	67,3	16,4	17,4	5,1	106,2	9,3	109,6
8	63,9	13,1	16,8	4,4	98,2	1,3	101,3
9	65,5	15,0	16,2	5,2	101,9	5,0	105,1

Note: Comma represents decimal point.

or potassium (treatment 9), the second year noticeably reduces the yield of hay and roots. Thus, fertilizers affect in the same manner the yield of forage alfalfa and its roots.

In order to determine more fully the effect of potassium fertilizers on soil fertility, we made a chemical analysis of the alfalfa roots for total nitrogen, phosphorous and potassium content. Nitrogen was determined by the micro-method of Kjeldahl. After ashing the plant tissues, phosphorus was determined by the method of Lebedyantsev, followed by colorimetric determinations by the modified method of Malyugin and Khrenova. Potassium was determined by the volumetric cobalti-nitrate method after wet ashing of plant material. The

results of the analysis are given in Tables 7 and 8.

As may be seen from the data (Tables 7 and 8), the use of potassium fertilizers not only increases the potassium content in roots, but also has a positive effect on the accumulation of phosphorus and, especially, nitrogen.

We may note, by comparing the various treatments of the experiment, that an increase in the amount of potassium is accompanied by a certain intensification of the accumulation of nitrogen and phosphorus in roots.

Of the treatments tested, the best was found to be treatment 7, in which 60 kg/ha K_2O were

Table 7

Influence of potassium fertilizers on the nitrogen, phosphorous and potassium content of alfalfa roots, % of absolutely dry matter

Treatment No.	Data for 1956, 1-year old alfalfa			Data for 1957, 2-year old alfalfa		
	In the layer 0-40 cm			In the layer 0-40 cm		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
1	1,891	0,550	1,018	2,082	0,628	1,060
2	1,892	0,581	1,057	2,086	0,624	1,041
3	1,947	0,568	1,079	2,088	0,634	1,053
4	1,992	0,616	1,179	2,128	0,642	1,147
5	2,032	0,609	1,159	2,170	0,685	1,203
6	2,037	0,649	1,192	2,197	0,682	1,237
7	2,054	0,644	1,241	2,207	0,704	1,278
8	1,830	0,589	1,007	2,042	0,624	1,073
9	2,002	0,551	1,101	2,110	0,647	1,187

Note: Comma represents decimal point.

Table 8

Influence of potassium fertilizers on the accumulation of nitrogen, phosphorus and potassium in the roots of alfalfa kg/ha

Treatment No.	Data for 1956, 1-year old alfalfa			Data for 1957, 2-year old alfalfa		
	In the layer 0-40 cm			In the layer 0-40 cm		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
1	123,8	36,0	66,6	201,6	60,8	102,7
2	124,7	38,3	69,5	201,7	60,3	100,6
3	130,4	38,0	72,3	207,7	63,0	105,7
4	137,8	42,6	74,6	214,0	64,6	115,4
5	143,6	43,0	81,9	225,8	71,3	125,2
6	147,8	47,0	86,7	230,0	71,3	129,5
7	148,9	46,5	89,9	234,3	74,7	135,7
8	115,5	37,2	63,5	200,5	61,7	99,4
9	139,3	38,5	76,6	214,9	65,8	121,4

Note: Comma represents decimal point.

turned under during plowing and 30 kg/ha harrowed in before sowing. The use of part of the amount of potassium (treatment 9) and also part of the amount of phosphorus (treatment 8) in the second year lowered somewhat the percentage of nitrogen, phosphorus and potassium contained not only in forage alfalfa, but also in its roots (Tables 7 and 8), as compared to treatments in which the full amount of potassium was applied the first year. This was shown in our article.¹ Thus, the change in the chemical composition of the root mass of alfalfa under the influence of potassium fertilizers is analogous to the change in the chemical composition of the tops.

In conclusion let us note that an increase in the amount of fertilizer to 90 kg/ha K_2O and its distribution in the soil in two layers (treatment 7) create better conditions for the accumulation of alfalfa hay and roots, increase their nitrogen, phosphorous and potassium content, and improve the quality of hay.

Conclusions

1. The use of potassium fertilizers for alfalfa under irrigation on meadow soils is sufficiently effective. Potassium exerts a positive

influence on the yield of forage alfalfa not only the first year after application, but also in following years.

2. Potassium fertilizer is an important factor in the accumulation of alfalfa roots. The effect of potassium is considerably lower the year of application than it is the following year. An increase in the amount of potassium to 90 kg/ha and its distribution in two layers in the soil (application of the main amount during plowing and of a small amount during harrowing prior to sowing) are accompanied by an increase in the yield of both forage alfalfa and its roots.

3. The use of parts of the total amount of potassium and phosphorus the second year of harvesting in the form of top-dressing, reduces the effectiveness of the fertilizers, judging by the yield of forage alfalfa and its roots.

4. The use of potassium fertilizers increases somewhat the potassium content and insignificantly the phosphorous content in the root system of alfalfa.

An improvement in the potassium nutrition of plants is accompanied by a certain intensification of the biological synthesis of nitrogen, which is evidenced by a slightly higher content of nitrogen in the roots of alfalfa.

¹Kaziyeu, M. A., and Kh. Z. Umarov. 1959. Udobreniye i Urozhay. No. 9.

Received June 10, 1959

CHARACTERISTICS OF CERTAIN SOILS OF THE PSKOV OBLAST'¹

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As known, the nature of the parent material determines to a great extent the chemical composition of soils, their water regime and the regime of plant nutrition. This is why in establishing taxonomic soil units one must distinguish between various types of soils forming on specific parent materials (2).

Binary parent materials are widespread in a number of areas of the Soviet Union because of the influence of former glaciation. The development of soil on these materials has a great agricultural significance. Such areas include the Pskov, Vologda, Kaliningrad, Leningrad, Arkhangel'sk and several other oblasts.

Binary parent materials, consisting of a coarse, sandy upper layer and an underlying layer of boulder clay loam, are distinguished by their favorable physical properties. The fact that glacial deposits are binary deposits is the result of the leaching of moraines by glacial melt water during glacial retreat, or by waters of a lacustrine-glacial origin. Investigators concerned with soils formed on binary deposits, stress their unusual properties created in the process of soil formation as a result of the structure of the parent material (1, 2, 3, 4).

Physiographic Conditions of Soil Formation

The Pskov Oblast', which is part of the Northwestern RSFSR, is in the area of the last glaciation (Valday) and is characterized by the alternation of plains and lowlands (Velikorets plain, Lovats lowland) with areas of hilly-morainic relief. In this part of the area, moraine belts are encountered, which are so-called terminal moraines. The terminal moraines, accompanied by slightly undulating sandur areas, have apparently formed at the margin of a glacier during its periods of stagnation. Moraine belts are distinguished by a very complicated arrangement of moraine hum-

mocks, lake depressions, or swampy flats, kames, eskers, terminal moraine ridges and other forms of relief. The southern part of the Opochets Oblast' is located within the limits of such moraine belts. The relief of the former agricultural experimental station is slightly undulating, changing in places into plains.

The climate of the area is moderately continental. Springs are early, long and cold. Because of this, sowing cannot be started earlier than the end of April to early May. The predominance of coarse sandy and sandy loam soils, which warm up rapidly, allows the sowing of summer crops at earlier dates.

The Pskov Oblast' is located in the sub-zone of the evergreen-broadleaf forest with a moss-herbaceous vegetation. The initial forest vegetation is almost entirely gone because the area has been cultivated since early times. The bedrock in the southwest consists of Devonian rocks (limestone, dolomite, marl, clay). They are covered by a thick layer of post-Tertiary loose deposits, and rarely outcrop. Thus, bedrock plays almost no part in soil formation.

Parent materials consist of glacial and fluvioglacial deposits, which often alternate with each other. Red-brown boulder clay loam, binary deposits, and boron sand predominate, stratified carbonate sand and sandy moraines (boulder sand) are found more rarely.

The boulder clay loam in the southwestern part of the area crops out only at ridge tops. It contains rare boulders of acid crystalline rock and limestone. The upper layer of the clay loam (about 100 cm) is leached, while the lower, from 100 cm down to 150 cm, contains limestone inclusions. As a rule, boulder clay loam is covered by a layer of gravelly sand 1 m thick. Such binary deposits are confined primarily to plain-like relief elements.

Soil Characteristics

The soils of the southwestern part of the Pskov Oblast' are little known, in spite of the fact that the region in which they are located was developed agriculturally long ago. In 1900, Sibirtsev (5) investigated the soils of the basin of the upper reaches of the Velikaya River in the Opochets district of the Pskov Oblast', and gave a general

¹ This article is based on material collected in the summer of 1956 during soil mapping of agricultural land use of kolkhoz Nova Zhizn of Opochetz Rayon, and previous territory of agricultural experimental station, Kun'insk Rayon, Pskov Oblast'. In the article the use is made of the soil analysis of profiles by the author in 1952 with T. A. Rozhnov in the National Forest of Belovezh (BSSR).

characterization of their physical and chemical properties. In 1902, Glinka (1) studied the post-Tertiary formations and soils of the Pskov, Novgorod, and Smolensk districts and noted the occurrence of unusual oak forest soils and sandy loams on clays.

During the investigation of soils in the previously mentioned part of the Pskov Oblast', our attention was drawn to the wide distribution of very unusual cropland varieties of sod-podzolic soils on binary deposits.

As mentioned earlier, a great role is played by parent materials in the formation of the soils of the area. The diversity of parent materials, characterizing the morainic area, also determines the great diversity of soils. Because of the reclamation of a great part of the area, cropland soils predominate here. Among these soils, the first place is occupied by cropland sod-podzolic soils, found primarily on binary deposits. The binary deposits consist of an upper layer of gravelly sand and an underlying layer of red-brown boulder clay loam. The upper layer varies in thickness from 30-40 cm and up to 60-100 cm. As a result of this, soils forming on binary deposits may differ in texture and in the intensity of the soil-forming process.

We distinguished the following types among the cultivated sod-podzolic soils of the southwestern part of the Pskov Oblast' according to the degree of development of the soil formation process: a) sod cryptopodzolic; b) sod moderately podzolic; and c) sod deeply podzolic (sod-contact-podzolic). The morphological description of the most typical profiles of these soils is given below.

Profile 202. Cultivated sod cryptopodzolic fine clay loam. Zhegalovo village, Kun'in district. Summit of a ridge. Clover pasture. Depth of profile, 105 cm. Does not effervesce.

Aplowed 0-21 cm. Grayish cinnamon-brown, fine clay loam, nutty-blocky.

BC 21-105 cm. Reddish-brown, sticky, fine boulder clay loam.

Not fully developed sod cryptopodzolic soils form at the summits of ridges and hills, where the upper sand layer is entirely eroded. The profile of the sod cryptopodzolic soil is shallow and consists of a plowed horizon, often containing a large amount of sand, and the soil-forming red-brown boulder fine clay loam. The upper layer of the clay loam is podzolized. These soils are used primarily under perennial grass.

Profile 76. Cultivated sod moderately podzolic sandy loam soil. Kostkovo village, Opo-chets district. Gentle slope of a ridge. Flax field. Depth of profile, 100 cm. Weak effervescence from a depth of 93 cm.

Aplowed 0-22 cm. Gray, sandy loam, coarsely blocky.

A₂ 22-40 cm. Pale-yellow, slightly whitish, gravelly sandy loam with boulders.

A₂B 40-61 cm. Yellowish red-brown clay

loam with a large amount of sand in the upper part, fine clay loam in the lower part.

C 61-100 cm. Red-brown heavy boulder fine clay loam.

Cultivated sod moderately podzolic soils form in the presence of a sand deposit 30-40 cm thick. Morphologically they have not only a podzolic horizon, but also an intermediate A₂B horizon of a yellowish-brown color. This horizon forms the contact between two layers and is texturally non-homogeneous. The entire sandy layer below the plowed horizon, as well as the intermediate A₂B horizon are podzolized.

Profile 250. Cultivated sod deeply podzolic sandy loam. Ushchitsy village, Kun'in district. Flat summit of a ridge. Under barley. Depth of profile, 120 cm. Does not effervesce.

Aplowed 0-31 cm. Gray, sandy loam, friable, blocky.

A₂ 31-63 cm. Yellow, sandy with inclusions of ortstein grains, friable.

A₂B 63-78 cm. Yellowish red-brown, non-homogeneous texture—sand tongues against a background of red-brown clay loam, reaching 80 cm in length.

C 78-120 cm. Red-brown fine clay loam.

Profile 199. Cultivated sod deeply podzolic, coarse clay loam. Zhegalovo village, Kun'in district. The lower third of a slope. Under corn. Depth of the horizon, 110 cm. Does not effervesce.

Aplowed 0-40 cm. Black, clay loam, coarsely blocky.

A₂ 40-47 cm. Yellow, sandy gravelly clay loam with boulders.

A₂B 47-52 cm. Ochre-yellow, fine clay loam, slightly sandy.

C 52-110 cm. Red-brown clay, sticky.

Profile 7. Cultivated sod deeply podzolized soil. Opo-chets district, Mostishche village. Flat summit of a ridge. Rye field. Depth of profile, 187 cm. Does not effervesce.

Aplowed 0-15 cm. Grayish cinnamon-brown, sandy, friable blocky.

B 15-63 cm. Slightly ochre, gravelly sandy with boulders, friable.

A₂ 63-130 cm. Whitish-yellow, fine sand with iron veins, friable.

A₂B 130-145 cm. Yellowish-brown coarse sandy clay loam.

C 145-187 cm. Reddish-brown coarse clay loam.

The deeply-extending podzolic horizon in these soil horizons is of a whitish-yellow, or pale yellow color. At the bottom it is replaced by the podzolized A₂B contact horizon. This

horizon reflects even deeper soil podzolization, since in this case, the upper part of the underlying clay loam is podzolized. The illuvial horizon precedes the podzolized horizon (Profiles 7, 18), but does not always have sharply defined boundaries.

The podzolic horizon in this case does not develop on top, but below at the boundary with clay. The reason for the formation of such a deep podzolized horizon, in the opinion of Glinka (1), is the rapid infiltration of soil solutions through the upper soil layer without interaction with the soil. Podzolization occurs in the lowermost horizons, where the solutions are held back at the boundary with clay and react with the sandy material. Unfortunately, Glinka does not give a chemical analysis of these soils.

In the description of the soil of the southern part of Belorussia (6), deeply podzolized soils on sandy boulder sandy loam underlain by sand resting on morainic clay loam are distinguished. Zavalishin and Nadezhdin (2) in characterizing the soil of the Kaliningrad Oblast' distinguished between cropland soils deeply podzolized, and unsaturated sod soils with weak remains of a podzolic horizon, on binary deposits. The binary deposits consist of sandy loam or coarse clay loam deposit underlain by boulder clay loam. In these soils the podzolic horizon is strongly extended, but poorly defined. Ponomareva (3) also found unusual weakly podzolized sod soils with a deep podzolic horizon and indications of gleyization on binary deposits (silty sandy loam on varve clay, or clay loam) in the central part of the isthmus of Karelia. She also believes that the contact horizon is podzolized, because the infiltration rate of soil solutions is slowed down at the boundary of two layers, so that their period of interaction with the soil is increased, which is one of the most important conditions for podzol formations. In describing the soils of the Belovezh Forest, developed on binary deposits, Rosanov (4) believes that the light-colored horizon in these soils has a closer resemblance to a gley horizon than to a podzolic horizon.

Thus, the problem of the nature of the light-colored contact horizon on binary deposits is not solved yet. Apparently the problem must be approached differently in each case. No evi-

dence of gleyization was found by us in summer in the soil profiles investigated. However, the contact horizon must probably experience a deficiency in oxygen during the rainy season, even with lateral inflow. This is why it is difficult to decide which process, podzolization or gleyization, predominates in soils on binary deposits, and during which season, without studying their moisture regime.

The genesis of cultivated soil is determined by comparison with a similar forest soil. Since we were not able to find a deeply podzolized soil in the forest of the southwestern part of the Pskov Oblast' because it had been extensively used for agriculture, we will describe the forest soil of the Belovezh Forest, which we assume to be analogous to sod-contact-podzolic forest soil.

Profile 18. Oak stand mixed with spruce with an undergrowth of hornbeam and aspen. The forest floor is covered with fern, goutweed, lupine, whortleberry, majanthemum, oxalis, vetch, reedgrass, and orchard-grass. The depth of the profile is 130 cm. Limestone fragments effervesce from a depth of 80 cm.

A_0 0-15 cm. Forest litter.

A_1A_2 5-14 cm. Cinnamon-brownish-whitish, friable, podzolized, sandy with small boulders, platy structure.

B 14-34 cm. Light cinnamon-brown, sandy, bouldery, friable.

A_2 35-44 cm. Whitish-yellow, sandy, gravelly, with a tongue extending into the next horizon.

A_2B 44-80 cm. Reddish-cinnamon-brown, coarse clay loam with boulders, very compact, podzolized tongues extend deeply down. The faces of individual particles are powdered with silica.

C 80-130 cm. Reddish-cinnamon-brown, coarse clay loam, less compact than the preceding horizon, fragments of limestone effervesce.

The description shows that the profile of the given soil has many similarities with the profile

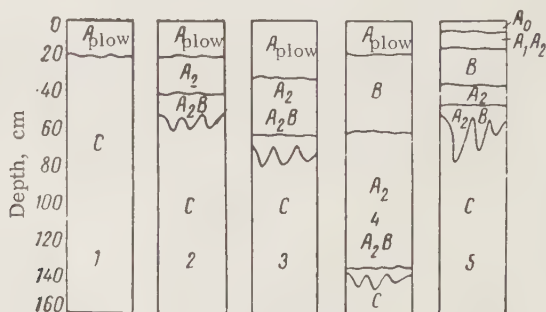


Fig. 1. - Structural profiles of soils on binary deposits.

Profiles: 1 - 202; 2 - 76; 3 - 250; 4 - 7; 5 - 18.

PSKOV OBLAST' SOILS

Table 1

Particle-size analysis by the method of N. A. Kachinskiy, % of dry soil

Profile Number	Soil	Depth, cm	Losses on treatment with HCl	Coarse earth	Diameter of particles, mm						
					in percent						
			1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	< 0.001	> 0.01		
202	Cultivated sod weakly podzolized clay loam on boulder clay loam	0-10	3,06	2,60	6,28	25,58	20,21	11,13	16,84	16,89	44,86
		25-30	2,62	0,70	2,08	8,38	25,57	10,51	18,06	32,78	61,35
		70-75	2,38	0,25	1,66	18,55	26,65	8,81	17,07	24,86	50,74
		105-110	4,31	2,50	15,13	24,46	20,58	6,94	11,81	16,77	35,52
76	Cultivated sod moderately podzolized sandy loam on a binary deposit	0-10	2,11	—	11,76	48,05	15,68	6,07	7,88	8,45	22,40
		27-31	1,21	12,63	14,27	54,04	14,19	4,42	7,60	4,27	16,29
		46-51	1,51	9,08	8,49	28,31	17,49	10,04	15,12	19,04	44,20
		70-75	2,14	—	3,64	19,65	15,18	14,52	22,89	21,98	59,39
		100-105	3,21	11,33	15,37	29,00	20,25	4,16	12,74	15,27	32,14
250	Cultivated sod deeply podzolized sandy loam on a binary deposit	0-10	3,08	—	9,94	52,78	13,94	6,28	8,21	5,77	20,26
		20-30	11,73	—	7,07	59,84	16,89	3,32	7,82	3,33	17,48
		35-40	1,13	1,55	6,11	70,72	15,46	1,51	2,66	2,41	6,58
		65-70	2,47	1,90	7,19	29,90	23,10	5,26	12,23	19,76	37,25
		110-120	2,16	7,20	11,30	30,85	18,73	6,06	11,71	19,19	36,96
7	Cultivated sod deeply podzolized sandy soil on a binary deposit	0-10	0,98	7,28	17,89	43,75	32,62	1,85	1,41	1,50	4,76
		20-25	1,31	7,85	32,56	56,19	5,37	0,96	1,86	1,75	4,57
		55-60	0,69	19,11	25,50	68,40	2,11	0,55	0,75	1,00	2,40
		105-110	0,67	2,47	5,27	73,67	15,38	1,61	1,85	1,55	3,40
		170-175	1,50	7,97	10,53	45,49	19,60	5,80	6,55	10,53	22,88
48	Sod deeply podzolized soil on a binary deposit	7-13	1,25	3,76	32,58	44,62	14,00	1,82	3,62	2,11	7,55
		20-26	0,94	6,16	36,11	44,59	11,29	2,15	2,81	2,11	7,07
		40-45	1,10	5,59	26,86	48,65	14,10	2,31	2,86	4,12	9,29
		65-70	2,41	2,00	16,34	43,63	16,47	1,37	3,77	16,01	21,15
		125-130	4,17	10,60	18,27	44,50	13,59	1,16	3,64	14,76	19,56

Note: Comma represents decimal point.

f sod deeply podzolized soil. In contrast to the cultivated soil, the profile of the forest soil has, as it seems, two podzolized horizons: A₁A₂, which is morphologically poorly defined as a result of its being colored with humus, and A₂ with A₂B, at the contact with the underlying boulder clay loam.

It may be assumed that in the soils of broad-leaf forests with a herbaceous cover, weakly acid solutions, forming as a result of the decomposition of plant residues, infiltrate through the water-permeable sandy layer and only slightly podzolize the upper portion of the soil profile (A₁A₂ horizon). The greatest part of these solutions seeps through the sandy to sandy loam layer to the contact surface with the clay loam, where it concentrates and dissolves the mineral portion of the lower horizons, podzolizing them more intensively. Because of annual plowing, there is no upper podzolized horizon in cultivated soils, and only one podzolized contact horizon remains.

In comparing the structure of the soil pro-

files on binary deposits, one may see how the podzolized horizon elongates and how its boundaries become diffuse (Fig. 1) depending on the thickness of the sand deposit.

The texture of the studied soils on binary deposits is shown in Table 1.

The water permeability of the soil depends on the thickness of the upper sand layer. Cultivated, sod cryptopodzolic clay loam, in which remains of a sand deposit persist only in the form of a sandy plowed layer, undergoes periodic excessive wetting at the surface. When the plowed layer and the underlying layer are saturated with moisture, the root system of plants becomes subject to anaerobic conditions. The possibility of the saturation of the upper layer during periods of prolonged rains is not excluded even when the sandy, water-permeable layer is shallow (moderately podzolized sod soils). Cultivated, sod deeply podzolized soils are under more favorable conditions. The upper, water-permeable layer is 60-100 cm thick. Atmospheric precipitation easily penetrates

Table 2

Humus, soil reaction, exchangeable acidities and exchangeable cations

Profile Number	Depth, cm	Horizon	Humus, % (according to Tyurin)	pH		Exchangeable cations			Exchangeable acidities (accord.to Sokolov)		Total N %	P ₂ O ₅ , mg/100 g of soil
				water	salt	Ca	Mg	H	Al	H+Al		
202	0-10	A _{plowed}	4,38	5,50	4,30	7,71	3,45	0,04	0,13	0,17	0,16	2,5
	25-30	B	0,68	4,80	3,50	6,02	3,86	0,13	2,60	2,73	—	7,5
	70-75	C	0,39	4,80	3,25	6,03	4,69	0,12	1,69	1,81	—	—
	105-110		0,25	6,00	4,55	5,79	3,70	0,03	0,06	0,09	—	—
250	0-10	A _{plowed}	3,10	7,50	6,50	14,27	1,56	0,01	0,02	0,03	0,11	40,0
	20-30	A _{plowed}	1,86	7,50	6,30	6,29	1,81	0,09	0,01	0,02	—	15,0
	35-40	A ₂	0,42	7,40	5,50	1,07	0,33	0,01	0,03	0,04	—	—
	65-70	A ₂ B	0,41	4,50	3,40	4,06	1,23	2,07	2,34	2,31	—	—
	110-120	C	0,30	5,10	3,60	6,55	2,63	1,16	1,44	1,60	—	—
199	0-10	A _{plowed}	7,61	6,90	5,70	11,15	3,54	0,02	0,05	0,07	0,19	10,0
	30-40	A _{plowed}	2,99	5,90	4,70	6,52	2,22	0,03	0,08	0,11	0,10	2,5
	41-47	A ₂	0,83	5,80	4,30	3,34	1,15	0,04	0,15	0,19	—	Trace
	48-52	A ₂ B	0,61	5,20	3,70	5,72	2,88	1,08	1,40	1,48	—	—
	70-75	C	0,52	5,00	3,60	8,28	4,52	1,09	1,10	1,19	—	—
	100-110		—	7,00	5,85	11,52	4,36	0,01	0,02	0,03	—	—
76	0-10	A _{plowed}	2,98	6,60	5,75	8,45	1,49	—	—	—	0,17	25,0
	27-31	A ₂	0,47	7,00	5,75	3,60	0,71	—	—	—	—	15,0
	46-51	A ₂ B	0,41	7,00	5,75	9,17	2,25	—	—	—	—	—
	70-75	C	0,49	7,10	5,85	7,35	1,43	—	—	—	—	—
	100-105		0,25	7,80	6,20	—	—	—	—	—	—	—
7	0-10	A _{plowed}	1,20	6,50	4,60	2,40	0,28	0,04	0,11	0,15	0,05	20,0
	20-25	B	0,52	6,65	4,85	2,11	0,10	0,02	0,07	0,09	—	20,0
	55-60	B	0,26	6,70	5,50	1,72	0,16	0,03	0,04	0,07	—	—
	105-110	A ₂	—	6,50	4,90	2,80	0,30	0,01	0,03	0,04	—	—
	170-175	C	—	6,90	5,60	7,54	1,40	0,02	0,04	0,06	—	—
18	0-5	A ₁₀	4,83	5,65	4,82	4,82	0,52	0,04	0,08	0,12	—	—
	7-13	A ₁ A ₂	1,41	4,74	4,09	1,27	—	0,03	0,74	0,76	—	—
	20-25	B	0,58	5,02	4,43	2,17	0,08	0,01	0,33	0,34	—	—
	40-45	A ₂	0,14	5,37	4,49	2,88	0,12	0,005	0,26	0,27	—	—
	65-70	A ₂ B	—	4,39	4,05	9,22	0,26	0,02	0,92	0,94	—	—
	125-130	C	—	7,81	7,42	57,01	1,24	—	—	—	—	—

Note: Comma represents decimal point.

through the sand layer to its contact surface with clay loam. The content of clay and silt increases sharply in the underlying clay loam. Depending on the amount of precipitation, the sand layer becomes either saturated with moisture, or water stagnates temporarily in the deep sand horizons at the contact with the underlying clay loam. Taking into account the gentle slope of deeply podzolized soils of the Pskov Oblast¹, the possibility of lateral inflow is not excluded. This is probably why gleyization rarely occurs at the boundary between two layers.

Table 2 gives data of chemical analyses which clearly show the difference between the

soils investigated. The humus content in the plowed layer of cultivated soils does not exceed 3%-4%. A deviation toward higher values is found only in Profile 199, characterizing the soil of the fallow field of the agricultural experimental station. The lowest humus content is found in the sod deeply podzolized soil, the upper layer of which consists of loose sand (Profile 7). All soil profiles show a sharp decrease of humus with depth. The distribution of acidity along the soil profile is even more indicative. Sod cryptopodzolic soils do not possess a morphologically defined podzolic horizon. In spite of this, the upper layer of the boulder clay loam parent material has an acid reaction as a result of the contemporary process of podzol formation

PSKOV OBLAST' SOILS

Table 3

Total chemical analysis, % of ignited substance

Profile No.	Depth, cm	Ignition loss	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	CaO	MgO	K ₂ O	Na ₂ O	P ₂ O ₅	SO ₃
76	0-10	4,33	82,57	0,60	9,42	1,78	0,06	1,16	0,68	2,56	0,79	0,34	0,03
	27-31	1,52	82,38	0,59	9,60	1,57	0,08	0,81	0,78	2,70	1,20	0,25	0,01
	46-51	2,50	77,12	0,67	13,40	2,52	0,06	0,65	1,02	3,08	1,30	0,13	None
	70-75	3,34	70,14	0,94	16,30	4,05	0,09	0,98	1,44	3,29	1,02	0,24	"
	100-105	2,16	77,36	0,61	11,41	3,67	0,10	1,33	1,26	2,83	1,13	0,25	"
250	0-10	5,85	82,03	0,47	9,32	2,34	0,09	1,42	0,78	2,54	0,58	0,38	0,03
	20-30	3,02	86,17	0,46	7,57	1,47	0,04	0,62	0,60	2,25	0,57	0,21	0,01
	35-40	1,25	87,69	0,62	6,06	1,20	0,03	1,04	0,28	2,29	0,68	0,07	0,01
	65-70	3,10	75,58	1,08	13,09	4,14	0,05	0,89	1,15	3,35	0,60	0,04	0,01
	110-120	3,00	75,31	0,92	12,97	4,28	0,04	1,15	1,35	3,10	0,77	0,06	0,01
7	0-10	1,89	88,36	0,29	6,12	0,86	0,05	0,61	0,29	2,09	1,10	0,19	0,01
	20-25	1,21	86,88	0,26	6,92	1,14	0,04	0,88	0,55	2,07	0,98	0,25	Trace
	55-60	0,71	86,54	0,19	7,42	1,13	0,03	0,69	0,53	2,06	1,49	0,15	Trace
	105-110	0,68	86,92	0,29	6,70	0,86	0,04	0,77	0,43	2,15	1,36	0,16	0,01
	170-175	1,34	83,12	0,49	8,92	2,11	0,07	0,94	0,75	2,62	0,67	0,26	0,01
18	7-13	1,77	91-92	0,33	3,80	0,86	0,05	0,50	0,38	1,34	0,58	0,19	0,01
	20-25	1,08	91-11	0,33	4,67	0,86	0,05	0,53	0,37	1,40	0,51	0,15	0,01
	40-45	0,85	89,80	0,37	5,40	1,29	0,07	0,42	0,26	1,84	0,43	0,09	Trace
	65-70	1,97	84,79	0,47	8,43	2,24	0,01	0,64	0,71	1,83	0,63	0,17	Trace
	125-130	2,44	85,49	0,41	6,61	1,59	0,03	2,39	0,70	1,80	0,71	0,21	Trace

Note: Comma represents decimal point.

The cultivated, sod moderately podzolized soil of the slope, formed over shallow-lying carbonate clay loam, is under the influence of the lateral sub-flow of hard carbonate waters. The aluminum in the carbonate clay loam, which moves with soil solutions, neutralizes soil acidity.

Sod deeply podzolized soils on binary deposits are distinguished by their deepest podzolization. Rozanov (4), in characterizing soils with a light-colored contact horizon, gives data which show that the contact horizon has a weakly acid reaction and even a reaction close to neutral. The contact between the sandy layer and the underlying clay loam layer in deeply podzolized soils of the Pskov Oblast' is expressed in the form of a light-colored intermediate sandy - clay loam A₂B horizon. This horizon is more acid than the podzolic horizon. This is precisely on this horizon that acid solutions act, infiltrating through the soil and stagnating a given period of time at the boundary of two layers, they promote leaching. As known, the depth to which acidity penetrates characterizes the degree of leaching of soils. Consequently, sod deeply podzolized soils must be considered as the most deeply leached soils. A maximum content of exchangeable aluminum corresponds to maximum acidity.

The distribution of bases along the profile of the previously mentioned soils is also characteristic of soils of the podzolic type: the amount of bases decreases in the podzolic horizon and increases in the underlying horizon.

The binary soil layer excludes the possibility of determining the degree of removal and accumulation of individual oxides. In the given case, it is only natural to expect a sharp differentiation of the quantitative ratios between oxides in the upper and lower layers. In the upper sandy - sandy loam layer silicic acids amount to 82%-88%, while alkali oxides predominate over alkaline earths. In the underlying clay loam layer, the content of silicic acids decreases noticeably and that of sesquioxides and alkaline earths increases correspondingly (Table 3). The sod deeply podzolized soil of the Belovezh Forest, being generally similar to the analogous cultivated soil of the Pskov Oblast' differs from it by its lower content of alkali oxides and its higher content of silicic acid.

Conclusions

1. Cultivated sod-podzolic soils on binary deposits are widespread in the areas studied in the southwestern part of the Pskov Oblast'. A special place is occupied among them by sandy - clay loam cultivated soils, having a deep podzolized horizon at the contact with the underlying boulder clay loam.

2. The contact horizon is podzolized, judging by its low active acidity and correspondingly high content of exchangeable aluminum. As a rule, no gleyization is observed because of the lateral outflow of water.

3. Because of their deep podzolization and

the always existing contact between the podzolized horizon with the underlying boulder clay loam, we call these soils of the Pskov Oblast' deeply-podzolized soils (sod-contact-podzolic).

4. It may be assumed that, in the virgin state, the sod deeply podzolized soils in the sod-podzolic sub-zone had two podzolized horizons in the soil profile. The upper, weakly podzolized horizon forms under the direct, but short-term influence of solutions forming during the decomposition of the forest litter. The contact horizon forms under the influence of acid solutions which seep through the soil and concentrate at the boundary between two layers.

5. Cultivated sod deeply-podzolized soils are characterized by an unusual moisture and aeration regime. In plains they may undergo swamping, but when they form on sloping surfaces gleyization does not occur because of lateral outflow, or occurs for very short periods. The soils are easily tilled, but require the application of organic and mineral fertilizers.

Soils with shallow sandy loam deposits (30-40 cm) and a shallow-lying underlying carbonate clay loam layer have much better agronomical properties.

Received December 7, 1959

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METHODS

THE LOWER LIMIT OF AVAILABLE MOISTURE FOR PLANTS IN PEAT SOILS

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Because of the development of meliorative construction, the area of peat soils under agricultural use has increased considerably in recent years. However, a series of properties of these soils, reflecting in particular their physical and hydrophysical characteristics, have not been studied enough. These include, among others, the permanent wilting of plants, which is one of the major hydrological soil constants necessary in meliorative and agronomical practice for determining the range of active moisture, for calculating the water balance of an area being drained, for elaborating drainage rates, and for determining the time for irrigation, etc. Whereas a large number of investigations is devoted to the study of this problem in mineral soils, there are only few works devoted to peat soils, such as those of Sereda (5), and Amnuil (1), in which absolute values of the wilting moisture for two types of peat soil are examined and an attempt is made to relate the wilting moisture values to the porosity of peat soils in one case, and their maximum molecular water capacity, in the second case.

N. I. Sereda indicated, on the basis of experiments with large samples (50 cm high) of sedge-hypnum-reed peat, that the wilting moisture is 40% of the porosity of peat soils. At the same time, such wilting moisture occurred only at a depth of 30-50 cm. In the upper layers, which contain more roots, the wilting moisture was 14%-21% of the pore volume in the layer from 0-10 cm, 25%-38% in the layer from 10-20 cm, and 28%-37% in the layer from 20-30 cm. In the experiments of N. I. Sereda, maximum consumption of all moisture available to plants probably occurred at a moisture of 14%-21%. The higher moisture content of lower-lying horizons, which are penetrated with difficulty by roots, indicates the presence of a certain amount of available, but not sufficiently mobile, moisture contained in large and blind pores. This is why we think that a permanent wilting moisture of 40% of the pore volume is slightly exaggerated, and that the expression of the wilting moisture in percent of the pore volume is unfortunate, since the porosity of peat soils is a very dynamic value.

In determining the wilting moisture in mineral soils from indirect indices, maximum hygroscopicity, maximum molecular moisture

capacity and other hydrological soil constants are used. However, the determination of the wilting moisture in peat soils from maximum hygroscopicity is difficult because the process of water vapor saturation of the samples to the state of equilibrium lasts several months (1).

The study of the maximum molecular moisture capacity in peat soils, as a value corresponding to the wilting moisture, is of great interest because the determination of the maximum molecular moisture capacity by the method of film equilibrium allows rapid and simple determination of the wilting moisture. At the same time it must be noted that the amount of moisture retained by the peat soil after pressing (method of film equilibrium) is not analogous to the moisture of the maximum molecular moisture capacity of mineral soils, because in the case of peat soils not only the moisture held by molecular forces (as in the case of mineral soils), but also a certain amount of intracellular moisture (osmotic) is taken into account. This is why the term maximum molecular moisture capacity is a conditional term as far as peat soils are concerned, since it does not reflect the nature of the forces which hold the moisture being determined by the method of film equilibrium.

Since this term was used before by many authors for this type of moisture in peat soils and also for the sake of brevity, we will retain this insufficiently accurate, but accepted terminology.

Our observations were aimed at the determination of the wilting moisture of plants developing on various types of peat, the study of the influence of the drainage and reclamation of peat soils on changes in wilting moisture, as well as the verification of the principle of the correspondence between the maximum molecular moisture capacity of peaty soils and wilting moisture, and the elaboration of certain methodological problems.

The wilting point was determined by the sprouting method (3). The method was expedient because the root system of plants, when developing in a limited volume of soil in an aluminum can, spreads in a dense network in the peat sample and completely assimilates the reserves of useful moisture. As a result, only

that moisture is determined which is not assimilated by plants, whereby this determination is not distorted by moisture contained in closed or large pores in which the effect of meniscus forces is not sufficient for supplying moisture to the rhizosphere. This is why the determination of the wilting moisture by the sprouting method is close to conditions in the plowing horizon of peat soils, i. e., that horizon in which the main mass of plant roots concentrates. Preliminary observations have shown that in high, intermediate and, to a great extent, lowland peat soils, the root system (barley in our experiments) becomes covered with mildew and rots, and the plant itself has a wilted appearance. In this case wilting moisture values were very unstable. To eliminate this, all plants were watered with the nutrient solution of Knop (solution of 1 g $\text{Ca}(\text{NO}_3)_2$; 0.25 g KH_2PO_4 ; 0.25 g MgSO_4 ; 0.125 g KCl and traces of FeCl_3 in 1000 cc of water). This provided for sufficiently satisfactory plant development (Fig. 1). Wilting moisture determinations were replicated five times. Such an experimental setup provided for the necessary uniformity of parallel observations. As a rule, the deviation of arithmetic mean values in this case was $\pm 6\%$ - 8% . For instance, in the experiment with herbaceous lowland peat (Vorshchakovo Massif, sample No. 6, Table 2), the following wilting moisture values were obtained: 260, 290, 268, 261 and 280, their arithmetic mean was 273%; the main, or square deviation in single determinations was in this case 13.5%, and the error of the mean was 2.7%.

In the first series of experiments (Table 1), the wilting moisture and the maximum molecular moisture capacity were determined for certain types of undrained peat soils of a primarily low ash content, and the influence of drainage on the wilting moisture and maximum molecular moisture capacity was studied.

were obtained for sphagnum lowland peats. Maximum molecular moisture capacity varied little as compared to the wilting moisture for various peats. For instance, the minimum value of the maximum molecular moisture capacity for eleven soils with natural moisture was 78% and the maximum, 102%. The remaining soils formed by sedge, woody, reed, Menyanthes, hypnum, and birch peats, had very similar maximum molecular moisture capacity values: 89, 88, 95, 98, 92, 88, 95 and 92.

The great amplitude of wilting moisture variations in various peat soils, obtained in pot experiments, and the very close maximum molecular moisture capacity values indicate that in peat soils there is no direct relationship between wilting moisture and maximum molecular moisture capacity.

The ratio between wilting moisture and maximum moisture capacity may be close to one, in individual cases. We observed it in reed and forest sedge peat (the ratio between wilting moisture and maximum molecular moisture capacity was 1.13 and 1.19) used in the experiments under natural moisture conditions, and also in those cases when the peat samples were dried.

For the majority of peats investigated in their natural condition, the ratio between wilting moisture and maximum molecular moisture capacity varied from 2.7-4.4.

In the second series of experiments (Table 2), made primarily on woody, woody-sedge, and sedge peat soils of a high ash content, the influence of peat reclamation on the wilting moisture and the maximum molecular moisture capacity was studied, and certain methodological problems were elaborated.

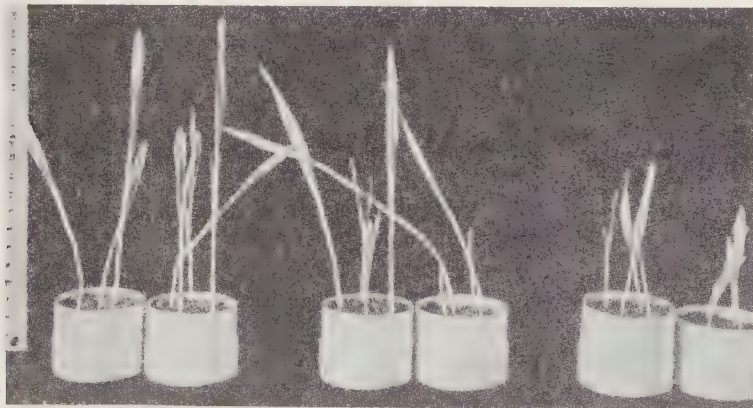


Fig. 1. - State of barley shoots grown on peat soils of a lowland bog. Left - watered with Knop's solution; center - watered with Knop's solution diluted in 2 parts of water; right - watered with water.

The results indicate that the wilting moisture for plants on the peat soils studied varies greatly (115%-390% by weight). Maximum values

The results of the second series of experiments indicate that in drained and reclaimed peats the ratio between wilting moisture and

AVAILABLE MOISTURE

Table 1

Permanent wilting moisture of plants on various undrained virgin peat soils

Sample No.	Type of peat	Degree of decomposition	Ash content	State of the peat soil used for tests	Permanent wilting moisture	Maximum molecular moisture capacity	Ratio between the permanent wilting moisture to maximum molecular moisture capacity
		In percent			In percent by weight		
1	Medium	15--20	2,3	Naturally moist	280	92	3,3
2	Lowland sphagnum	15--20	6,1	"	390	95	4,1
				After drying at 25-30°C	255	78	3,3
3	Woody	50--55	13,7	" " " 70°C	107	68	1,6
				Naturally moist	233	88	2,7
				After drying at 25-30°C	71	74	1,0
4	Sedge	35--55	5,4	" " " 70°C	76	42	1,8
				Naturally moist	282	89	3,2
				After drying at 25-30°C	90	73	1,2
5	Reed	Not det'd.		" " " 70°C	54	49	1,1
6	Sedge forest	30	7,2	Naturally moist	115	102	1,1
7	Reed	35	17,5	"	117	98	1,2
8	<u>Menyanthes</u>	25	5,9	"	270	88	3,1
9	Woody	45--55	7,2	"	389	88	4,4
10	Hypnum	10	3,7	"	212	78	2,7
11	Birch	50	7,2	"	335	95	3,5
					326	92	3,6

Note: Comma represents decimal point.

maximum molecular moisture capacity in all treatments of the experiment was 2 for the plowed horizon (2.0; 1.9; 2.0; 2.2). In deeper horizons, where temperature and moisture variations have a lesser amplitude and the influence of agricultural practices is weakened, this ratio, as well as the absolute values of the wilting moisture, is slightly higher (for instance, drained and reclaimed and non-drained virgin and of the Voroshchakovo sovkhoz). Comparison of the wilting moisture of plants on reclaimed, drained and unreclaimed land, as well as the ratio between it and the maximum molecular moisture capacity show that these values vary greatly depending on the ash content, degree of decomposition and the botanical composition of peat, and also on the meliorative and agricultural practices taken to reclaim these soils.

Data in Table 2 also show that there is no relation between the wilting moisture and the maximum molecular moisture capacity in the cultivated plowed horizon, or in the upper and lower horizons of peat soils.

The results of the investigations, given in Table 2, allow certain comments to be made on experimental methodology. It is usually recommended that peat be ground with a meat grinder when determining a series of peat soil constants, including the wilting moisture. This only explicates the already awkward

method of investigation. This method of grinding peat during soil investigations was apparently taken from investigations of peat for industrial purposes, when peat pulp or crumbs left by cutters were studied. In determining the wilting moisture, as well as in the majority of other soil investigations, such a method of processing the upper horizons of cultivated peat soils is unjustified because during plowing peat is chopped up and additional grinding with a meat grinder is unnecessary, as data in Table 2 show. For the deeper horizons of cultivated land and virgin peat such treatment is unjustified because agricultural practices do not reach into these horizons.

The experiments described show that, as a rule, the wilting moisture of peat soils and their maximum molecular moisture capacity are not equal. In this respect peat soils differ from mineral soils, for which Volbuyev (2) substantiated the assumption of Lebedeva (4) of the close relation between maximum molecular moisture capacity and wilting moisture, because of the specific properties of peat, determined by its plant origin. However, indirect methods of determining the wilting moisture of plants on mineral soils were criticized by Mitscherlich (7), Da Costa (6), Dolgov (3), and others because all these methods give only approximate values. But if indirect methods of determining the wilting moisture of mineral soils were subject to just criticism, which

Table 2

Permanent wilting moisture of plants of cultivated land, drained and virgin peat soils with a high ash content

Site	Sample No.	Treatment	Depth, cm	Type of peat	Degree of decomposition	Ash content	Permanent wilting moisture	Maximum molecular moisture capacity	Ratio between permanent wilting moisture and maximum molecular moisture cap.			
					In percent	Peat						
						Not ground	Ground	Not ground	Ground	Not ground	Ground	
Pekhorka	1	Drained plowed bed	0—20	Woody sedge	40	15,4	155	124	76	69	2,0	1,8
	2		20—40	"	50	41,5	150	140	75	80	2,0	1,8
	3	Drained	40—60	Sedge woody-herbaceous	45	69,8	110	105	54	76	2,0	1,4
	4	Virgin land	0—20		55	59,5	197	195	80	70	2,5	2,8
	5		40—50		60	18,6	240	230	75	73	3,2	3,2
Voroshchakovo	6	Non-drained virgin land	0—10	Lowland herbaceous	35	23,2	273	280	91	86	3,0	3,3
	7		30—40		35	10,4	250	300	91	87	2,8	3,4
	8		60—70		55	9,1	370	374	95	102	3,9	3,7
	9	Drained and reclaimed bed	0—20	Lowland woody	45	43,6	120	120	64	64	1,9	1,9
	10		30—40	"	55	10,0	240	270	88	88	2,7	3,1
	11		60—70		30	9,8	230	329	92	87	2,5	3,7
Yakhroma	12	Drained and reclaimed bed	0—20	Lowland woody								
	13	(under grass for 30 years)	20—40		55	60,1 28,2	87 180	81 —	41 77	44 75	2,0 2,3	1,8 —
Yakhroma	14	Drained and reclaimed bed (under vegetables for 10 years)	0—20	Lowland woody	50	35,3	144	145	75	68	2,2	2,1

Note: Comma represents decimal point.

cast doubt on their reliability, the results of the experiments described allow us to assert that the only reliable method of studying the wilting moisture of peat soils is its direct determination in biological tests.

Conclusions

1. The wilting moisture of most virgin or cultivated peat soils is 2-4 times higher, as a rule, than that determined by Lebedev's method of film equilibrium.

2. The wilting moisture of plants and the moisture determined by the method of film equilibrium agree only for a limited number of peat soils, or the agreement occurs as a

secondary phenomenon after drying.

3. Reliable data on the wilting moisture of plants on peat soils may be obtained only in biological experiments. The use of indirect methods for determining the wilting moisture of peat soils is unjustified.

4. In making pot experiments on the wilting moisture of lowland, intermediate, and high peats, the peat mass of the plowed horizons of cultivated peatbeds and lower horizons of virgin and reclaimed soils must not be ground artificially and the plants must be watered with a nutrient solution (for instance, Knop's solution).

5. A critical problem at this time is the prediction of the changes in the wilting moisture

f the plowed horizon of peat soils in the process
f reclamation.

Received October 26, 1959

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COMPARATIVE STUDY OF METHODS OF DETERMINING WATER-PERMEABILITY UNDER CONDITIONS OF SOD-PODZOLIC SOILS OF THE MOSCOW OBLAST¹

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The water permeability of soil is one of its most important hydrophysical properties. Without a knowledge of this property it is impossible to conduct properly certain operations, such as the drainage of swampy areas, field irrigation, etc. It is important to select the proper method of determining the water permeability of soil, since the results obtained depend to a great extent on the selection of the method.

Our study has the object of comparing various methods of determining the water permeability of soil. The fact that the lateral spreading of water from the instrument used influences the results obtained in field determinations of the water permeability of soil was taken into account. This problem had been studied by many investigators (5, 1, 6, 3, and others). In addition, we made tests on the influence of the size of small flooded areas on the water permeability of soil.

The well-known method, proposed by N. S. Nesterov, for eliminating the lateral spreading of water is based on the use of an enclosure for obstructing the lateral flow of water from the measuring cylinder in the instrument used. The method consists of driving two cylinders to a certain depth (5-7 cm) into the soil and filling them with water. It is assumed that the water spreads out from the outer enclosure only and moves strictly down along the soil profile from the inner enclosure. Thus, according to the principle of this method, observations on the decrease of water in the inner enclosure should give water permeability values undistorted by the influence of lateral spreading (6). This idea was used and developed by Doyarenko (4), N. A. Kachinskiy (6), and others determining quantitative results for many USSR soils. Soz'ykin (8), Antipov-Karatayev (1), Kachinskiy (7), Vaylert (2), and others showed that a double enclosure does not prevent the lateral spreading of water during determinations of the water permeability of soil.

Field experiments were conducted at the V. R. Vil'yams All-Union Forage Institute in the Moscow Oblast¹ in June, July and August, 1957.

The vegetation and soil of the plots selected

¹The work was done under the supervision of Professor N. A. Kachinskiy.

for the experiments were:

1. Sod-podzolic medium clay loam on an eroded clay loam surface moraine under a mixed southern taiga forest (Profile 1).

2. Sod-podzolic medium clay loam on an eroded surface moraine under perennial grass harvested the second year (clover and timothy) (Profile 2).

Profile 1

A₀ 0-4 cm. Litter of leaves and woody debris; dry at the surface and moist at the bottom dark-brown, loose, consisting of semi-decayed leaves and stems; a small amount of live roots of herbs are found in the lower part.

A₁ 4-14 cm. Humus-accumulative horizon. Moist, gray, brownish, clay loam, blocky-granular with a weak structure and moderately compact. There is a large number of roots and earthworms and larvae. The transition to the A₂ horizon is diffuse.

A₂ 14-32 cm. Podzolic, moist, whitish clay loam, slightly foliated, moderately compact, containing a large number of worm holes and small ortstein; there are less roots than in the A₁ horizon; penetrates in pockets into the B₁ horizon.

B₁ 32-58 cm. Moist, reddish-brown, dark blue along fissures, mottled by tongues extending from the A₂ horizon (SiO₂), fine clay loam, nutty, fissured, compact; there are only a few roots, predominantly along fissures.

B₂ 58-85 cm. Very moist, reddish-brown, dark blue along fissures, fine clay loam, divided vertically. Considerably compact, with alluvial crusts along fissures and many manganese streaks. The transition to the B₃ horizon is gradual.

B₃ 85-130 cm. Very moist, red-brown, very gleyey in places, fine clay loam, yields sharp-edged particles where eroded, considerably compact, fissured, sticky, with alluvial crusts along fissures; there are few roots, manganese streaks, the texture becomes coarser toward the bottom and the B₃ horizon gradually changes into a layer of a clay loam, sandy, loam, red-brown gleyed moraine.

WATER PERMEABILITY

Table 1

Particle-size analysis and certain physical properties of sod-podzolic soil, %

Plot	Horizon and depth, cm	Specific weight		Total porosity, %	Loss on treatment with 0.05 n HCl	Diameter, mm							
		solid phase	bulk			1—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	<0,01	>0,01
Under forest	A ₀ 0—4	—	—	—	—	—	—	—	—	—	—	—	—
	A ₁ 4—14	2,56	1,20	53	1,2	3,5	12,7	52,9	9,4	11,4	10,1	30,9	69,1
	A ₂ 17—25	2,60	1,46	44	0,6	2,5	19,2	50,4	9,7	10,5	7,7	28,0	72,0
	B ₁ 40—50	2,64	1,58	40	1,4	1,0	6,7	47,5	8,2	9,2	27,5	44,9	55,1
	B ₂ 60—70	2,66	1,70	36	1,2	1,5	7,4	43,0	9,2	9,9	29,1	48,2	51,8
	B ₃ 90—100	2,66	1,64	38	1,0	2,3	6,4	42,0	8,9	9,5	30,9	49,3	50,7
	C 140—150	2,72	1,64	40	0,5	25,2	18,9	18,7	5,3	8,5	23,4	37,2	62,8
Under grass	A _p 5—15	2,60	1,33	48	0,4	2,1	6,5	61,1	10,0	10,7	9,2	29,9	70,0
	B ₁ 40—50	2,67	1,59	40	0,7	0,5	0,0	58,3	1,3	8,2	30,4	39,9	60,0
	B ₂ 60—70	2,72	1,61	40	0,7	0,5	3,7	44,1	12,3	10,3	28,4	51,0	49,0
	B ₃ 90—100	2,64	1,67	36	1,2	1,7	1,6	44,2	8,2	12,8	30,3	51,3	48,7
	C 130—140	2,68	1,67	37	0,7	4,2	12,6	33,1	7,7	14,7	27,0	49,4	40,6

Note: Comma represents decimal point.

Profile 2 is the same as in the forest, except that the A₁ and A₂ horizons are replaced by the plowed layer 22-25 cm thick. In spite of the fact that the field was under clover and timothy, the plowed layer is considerably compact and almost structureless (cloddy).

properties of these soils are given in Table 1; the initial moisture in the soils during permeability determinations is given in Table 2.

The following methods and instruments were used in the experiments:

Particle-size analysis and certain physical

1) the cylindrical device of N. A. Kachinskiy

Table 2

Several hydrophysical properties of sod-podzolic soils

Plot	Depth, cm	Total water capacity	Natural	Relative	Plot	Depth, cm	Total water capacity	Natural	Relative
			moisture dur. permeability determinations					moisture dur. permeability determinations	
		in percent by weight					in percent by weight		
Under forest	0—4	123	31	25	Under grass	0—5	25,6	12	47
	4—10	29,6	18	61		5—10	24,5	12	49
	10—20	21,5	16	74		10—20	21,4	13	61
	20—30	22,5	17	76		20—30	20,1	16	79
	30—40	21,6	19	88		30—40	20,2	20	99
	40—50	18,2	30	110		40—50	20,2	22	108
	50—60	18,2	20	110		50—60	26,1	21	80
	60—70	20,7	20	97		60—70	27,5	23	84
	70—80	21,4	19	89		70—80	22,3	24	107
	80—90	20,7	20	97		80—90	20,0	22	110
	90—100	19,7	20	100		90—100	21,0	21	100

Note: Comma represents decimal point.

and Z. A. Korchagina with a Mariotte bottle (new model);² 2) N. A. Kachinskiy's tubes with alternating water pressure for determining the water permeability along each horizon; 3) the method of small flooded areas, using frames of the following sizes (in square meters) and combinations:

0.25 x 0.25; 0.5 x 0.5; 1 x 1; 2 x 2;
0.1 x 0.1 (0.25 x 0.25)³; 0.25 x 0.25
(0.5 x 0.5);
0.5 x 0.5 (1 x 1); 1 x 1 (2 x 2);
0.25 x 0.25; 0.25 x 0.25 (0.5 x 0.5);
0.25 x 0.25 (1 x 1).

4) Antipov-Karatayev (1), and Kachinskiy's (7) method of an isolated soil column (1 m² in area and 1 m high).

The frames were tightly set into cuts made with a knife to a depth of 7-8 cm in the soil at a distance from each other corresponding to their size.

The tests were replicated three times. The temperature of the water was measured constantly during the experiments. The final results were, of course, reduced to a temperature of 10°C (according to Hazen's formula) when calculating water permeability.

The results of determinations of the water permeability of soil are given in Figure 1, A and B.

Let us first of all examine the data on the water permeability of soil obtained by the tube method along each horizon in the forest and in the field. Figure 1, A-a shows that the permeability of sod-podzolic soil in the forest is sharply differentiated according to horizons. It is 36 times higher in the upper layer (forest litter) than in the underlying A₂ horizon. It decreases even more sharply in the B₁ and B₂ horizons. Such a permeability distribution closely agrees with other soil properties and the genesis of individual horizons. The loose, semi-earthly litter, the porosity of which reaches up to 70%, lets water pass through rapidly, whereby the water spreads more at the surface than in the humus horizon. The lowest permeability was found in the illuvial B₂ horizon of the forest soil. This horizon has a low porosity (less than 40%) so that water in it can move only by capillarity.

The permeability of the field soil, even in the plowed horizon, is much lower than in the upper horizons of the forest soil (Fig. 1, B-a),

because of the absence of a litter and the fact that the porosity of the plowed layer is primarily in the form of capillary pores.

Let us evaluate the data obtained by various methods on the porosity of soils from the surface down.

Forest plot. When determining water permeability by the cylindrical method of Kachinskiy and Korchagina, the instrument was driven into the soil to a depth of 3 cm. Because the earthy litter was 4 cm thick, only the permeability of this layer was measured. Naturally it was very high, up to 40 mm of the water per minute (Fig. 1, A-b). In order to correctly determine the permeability of the A₁ horizon with this apparatus, the litter must be removed.

The other two methods were used to determine the permeability of both the litter and the underlying mineral soil horizons. In this case, the lowest permeability was recorded when using the method of the isolated column, because in this method the lateral spreading of water from the column was completely eliminated.

Even though a water border guard was used in the method of concentric squares, the water permeability was still four times higher than in the isolated column method. Consequently, the lateral spreading of water cannot be eliminated when the surface horizon is very permeable.

Field plot. On this plot, different results were obtained when comparing the various methods. The layer under perennial grass was very compact. Its pores were primarily capillary pores. In this case the water losses from lateral spreading were minimal. This is why the permeability values obtained with the apparatus of Kachinskiy and Korchagina and those obtained by the method of small flooded areas were very close (Fig. 1, B-b).

Let us examine the permeability values obtained from flooded areas of various sizes without water border guards. The results differed for the forest and field plots (Fig. 1, A-b and B-C).

In the forest, as we already mentioned, the upper soil horizons are very permeable and are underlain by the B₁ horizon of a low permeability. Under these conditions intense lateral spreading occurs, which is the more intense, the smaller the area of the squares. In this case, the ratio between the perimeter and the area of the square is of importance. For instance, the ratio between the perimeter and the area of a frame 0.25 x 0.25 m² is 16, while for a frame 2 x 2 m², it drops to 2. In conformity with this, the permeability values in the forest for frames of varying sizes without water border guards varied. The lowest value was obtained when using a 2 x 2 m² frame, and the highest, with a 0.25 x 0.25 m² frame (Fig. 1, A-c).

As may be seen from Fig. 1, A-c, close average values were obtained for various frames (without a water border guard) in the field plot.

²N. A. Kachinskiy and Z. A. Korchagina's apparatus is described in the catalog for the International Exhibition of Agricultural Instruments in Moscow in 1959. It consists of a cylinder of a capacity of 1 liter made of transparent plastic. The cylinder is provided with a cutter (for insertion into the soil) and a lid with an attachment for supplying water and a Mariotte bottle. The wall of the cylinder is graduated to show the thickness of the layer and the volume of water penetrating into the soil.

³In parenthesis are given the dimension of protective frame.

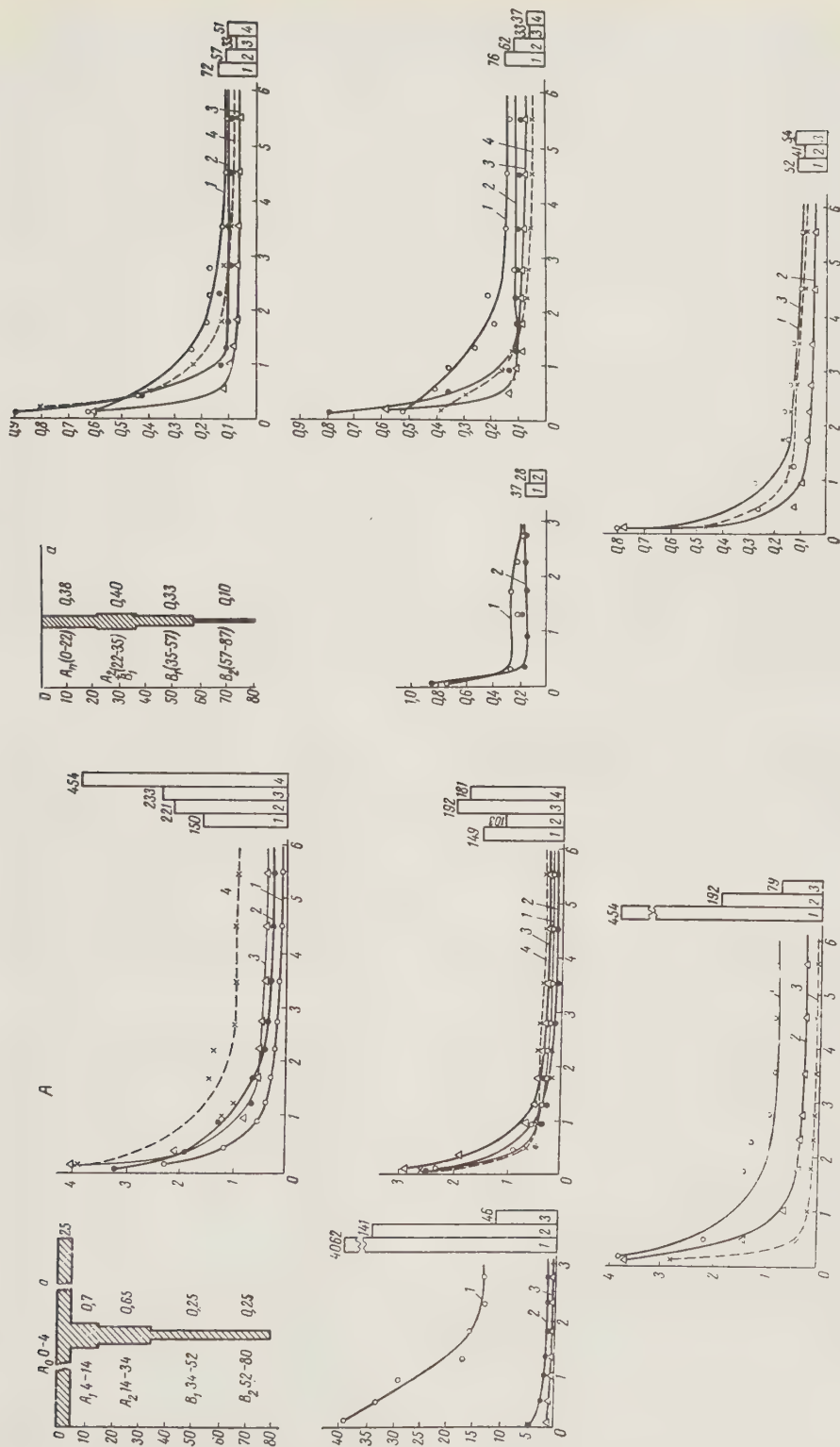


Figure 1

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Fig. 1. - Results of the experiment on the water permeability of soil

A - water permeability of sod-podzolic soils under a mixed forest; B - same under perennial grass. a - water permeability of soil along genetic horizons in mm/min. Tube method (H per 10-0 cm, temperature, 10°C); b - water permeability of soil as determined by the various methods. (H, 5 cm, temperature, 10°C). 1 - Kachinskiy's apparatus with Mariotte bottle; 2 - method of frames 0.25 x 0.25 (0.5 x 0.5) m²; 3 - method of isolated soil column; c - water permeability of soil depending on the size of frames - without water border guard. (H, 5 cm, temperature 10°C). 1 - frames 2 x 2 m²; 2 - 1 x 1 m²; 3 - 0.5 x 0.5 m²; 4 - 0.25 x 0.25 m²; d - water permeability of soil depending on the size of frames with various combinations of water border guards. (H, 5 cm, temperature 10°C). 1 - frames 1 x 1 m² (2 x 2); 2 - 0.5 x 0.5 m² (1 x 1); 3 - 0.25 x 0.25 m² (0.5 x 0.5); 4 - 0.1 x 0.1 m² (0.25 x 0.25); e - water permeability of soil depending on the width of the water border guard. (H, 5 cm, temperature, 10°C). 1 - frames 0.25 x 0.25 m² without guard; 2 - 0.25 x 0.25 m² (0.5 x 0.5); 3 - 0.25 x 0.25 m² (1 x 1).

Note to Figures A and B. Columns are shown on the right of the coordinates. Numbers in the columns correspond to the numbers of the water permeability curves. Numbers above the columns indicate the absorption of water by the soil in mm of the water column in 6 hours (except for Figures A-b and B-b, where the numbers above the columns indicate the absorption of water by the soil in millimeters of the water column in 3 hours of observation).

The results of permeability determinations with squares of various sizes using various water border guards also differed for the forest and the field. In the forest plot, where the lateral spreading of water is high during permeability determinations, the use of water border guards greatly reduces the water losses in a given square (Fig. 1, B-c-d), while the size of the squares in this case affects the permeability determinations very little (Fig. 1, A-d). However, the width of the water border guard noticeably affects permeability values in the forest; the wider the border, the lower the permeability of the soil in a given square (Fig. 1, A-e).

In the field plot, where little water spreads to the side, the use of a water border guard around a given square has almost no effect on the absolute values of soil permeability (Fig. 1, B-c-d-e).

Conclusions

1. When determining soil permeability, large amounts of water spread to the side only when highly permeable upper soil horizons (in our case in the forest) are underlain by horizons of a low permeability. In order to obtain more accurate results under these conditions when using the method of flooded areas, concentric squares must be used with water border guards in the peripheral layer. Even better results are obtained with the isolated soil column method.

2. The lateral spreading of water in friable, highly permeable soils increases as the area of the squares is decreased. However, when a protective border is used, even as small as 0.25 x 0.25 m², the spreading of water from the inner border (0.1 x 0.1 m²) decreases considerably. This is why it is important to increase not only the area of the squares, but also the ratio between the protective and measuring borders.

3. In areas where the soil is compact and has primarily capillary pores, the lateral spreading of water in the flooded areas is insignificant. However, in order to obtain constant soil permeability characteristics, squares with water border guards must also be used in

this case.

4. The apparatus of Kachinskiy is most suitable for determining soil permeability along individual genetic horizons, or soil layers differing in texture. This method should be used in conjunction with the method of small flooded areas.

A great advantage of Kachinskiy's method is the small amount of water needed when working with his instrument.

Received January 1, 1960

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INFLUENCE OF VARIOUS CONCENTRATIONS OF GASEOUS OXYGEN IN THE AIR OF THE SOIL ON OXIDATION-REDUCTION CONDITIONS

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The role of free oxygen in the life of plants and animals is well known. Physiologists know which oxygen concentrations are optimum, and which concentrations are limiting for life processes. In general, the role of oxygen in the life of soil and organisms inhabiting it is clear. It is known, for instance, that when the soil has sufficient free oxygen, aerobic processes take place in it, while when there is a deficiency of oxygen, anaerobic processes develop.

But under which oxygen concentrations do aerobic and anaerobic processes take place, when does the transition from the first to the latter and vice versa occur, and how do various concentrations of gaseous oxygen affect the agronomically important soil properties. These are unresolved problems that need study.

Experimental method. Organic residue was thoroughly separated from air-dried soil samples. Then 1.75 g of ground and sieved (through a 0.25 mm opening sieve) clover roots were added to each 250 g soil sample. The soil was placed into glass vessels, brought to a moisture of 60% of the total moisture capacity, and then the vessels were connected to a special apparatus which provided for the passage of a set amount of a gas mixture through the soil. The gas mixture consisted of 0% to 20% O_2 and 100% to 80% N_2 .

The experimental soil samples were taken from the plowed horizon of sod medium podzolized coarse clay loam at the experimental station of the Timiryazev Agricultural Academy's field husbandry and from the chernozem fine clay loam of the Azov region. The experiment lasted 30 days. It was replicated twice. During the experimental period the temperature of the soil varied from 16-22°C. The amount of liberated carbon dioxide, absorbed by 0.1 n Ba(OH)₂, was measured every five days and titrated against 0.1 n $H_2C_2O_4$ with phenolphthalein.

Results. Table 1 shows that in both sod-podzolic soil and chernozem the oxidation-reduction potential (Eh) increased gradually as the content of oxygen in the gas mixture was increased. The transition from anaerobic to aerobic conditions in the sod-podzolic soil occurred at 5% oxygen and the rH_2 was 26.5. At 10% oxygen the rH_2 was 28.17 and at 20% oxygen, 29.36.

The transition boundary to aerobic conditions in chernozem was found at an oxygen content of 2.5%, the rH_2 being 27.2. At 10% and 20% oxygen the rH_2 was 28.10 and 28.43, respectively.

Judging by the amount of FeO removed in various extracts from sod-podzolic soil, we may also state that the transition from anaerobic to aerobic conditions occurs when the oxygen content in the gas mixture is about 5% (ferrous oxide was determined in water, salt and sulfuric acid extracts at a soil:extract ratio of 1:5; 1:2.5 and 1:10, respectively, with LL'-dipyridyl according to the method of Kazarina-Oknina [1] as modified by Kopteva [2]).

In the absence of oxygen in the sod-podzolic soil, ferrous oxide was found not only in the sulfuric acid extract, but also in the salt extract and even in the water extract (0.67 mg). In the presence of 5% oxygen in the soil, the content of ferrous oxide in the sulfuric acid extract decreased sharply, only traces of it were found in the salt extract, and it was altogether absent in the water extract.

The amount of aerobic and anaerobic saprophytic microorganisms varied with varying contents of free oxygen.¹ These variations were most pronounced in sod-podzolic soil.

During the change of oxidation-reduction conditions in sod-podzolic soil, associated with the differential oxygen content, more noticeable changes in the reaction of the medium occur, more intermediate products and more lower and higher oxide forms of organic and mineral compounds form which cause more noticeable changes in the composition and amount of aerobic and anaerobic microflora. Thus, anaerobic conditions are created and more anaerobic bacteria are found (hundreds of millions of cells per 1 g of soil) when the oxygen content is 0%-5%. Their amount decreases sharply under complete aeration (20% O_2). The amount of aerobic microorganisms increases gradually as the oxidation-reduction potential increases, even though this increase is not that great. It is known from the micro-

¹Microbiological determinations were made in consultation with V. F. Nepomiluyev.

Table 1

Changes in the oxidation-reduction potential and the content of ferrous oxide and microorganisms in soil depending on the concentration of gaseous oxygen

Experimental treatment	Moisture, %	Eh, mV	pH of the water suspension	FeO in mg per 100 g of dry soil		Total amount of microorganisms in millions per 1 g of soil, growing on meat-peptone agar	
				Extract		Anaerobic	Aerobic
				1 n KNO ₃	0.1 n H ₂ SO ₄		
Sod podzolic soil							
Initial soil	1,1	—	6,0	0,00	—	—	—
I $\frac{0,0}{100,0}$	25,6	132	6,6	4,21	107,55	387	370
II $\frac{0,5}{99,5}$	25,8	141	7,0	1,81	74,2	779	389
III $\frac{2,5}{97,5}$	25,7	218	6,9	0,93	57,6	465	464
IV $\frac{5,0}{95,0}$	25,9	387	6,8	0,03	15,2	413	816
V $\frac{10,0}{90,0}$	25,6	482	6,3	0,03	6,8	38	856
VI $\frac{20,0}{80,0}$	25,8	509	6,2	0,03	1,7	11	878
Chernozem							
Initial soil	3,1	—	7,2	0,00	0,2	—	—
I $\frac{0,0}{100,0}$	36,7	154	7,4	0,07	12,6	298	137
II $\frac{0,5}{99,5}$	37,1	221	7,5	0,00	0,3	271	147
III $\frac{2,5}{97,5}$	36,9	354	7,7	0,00	0,3	225	256
IV $\frac{5,0}{95,0}$	37,1	378	7,7	0,00	0,3	209	264
V $\frac{10,0}{90,0}$	37,1	387	7,6	0,00	0,1	209	279
VI $\frac{20,0}{80,0}$	37,0	403	7,5	0,00	0,00	195	329

^aThe numerator indicates the oxygen content, the denominator — nitrogen in the gas mixture in percentage of volume.

Note: Comma represents decimal point.

biological literature that the life activity of aerobic microorganism does not necessarily require the presence in the medium of a high content of oxygen; on the contrary, they may develop very well even when the partial pressure of oxygen is low. This is why a change in the oxygen regime does not strongly reflect on the number of aerobic microorganisms in the soil.

The number of aerobic microorganisms grad-

ually increases and that of anaerobic microorganisms decreases in chernozem as the oxidation-reduction potential increases. Apparently a large place among anaerobic microorganisms is occupied in the given case by facultative anaerobic microorganisms. The regular increase of the amount of aerobic microorganisms and the decrease of anaerobic microorganisms when Eh and rH_2 increase in chernozem are apparently associated with the fact

GASEOUS OXYGEN

Table 2

Changes in the contents of ammonium and nitrate nitrogen and phosphates available to plants depending on the concentration of gaseous oxygen in the soil

Experimental treatment	CO ₂ liberated in 30 days	Nitrate N	Ammonium N	P ₂ O ₅ according to Chirikov in groups in the treatment worked over once		
				I	II	III
in mg per 100 g of dry soil						
Sod-podzolic soil						
Initial soil	—	2,3	8,44	7,6	30,9	86,9
I $\frac{0,0}{100,0}$	184	0,0	9,6	3,1	24,3	98,0
II $\frac{0,5}{99,5}$	514	0,2	9,4	4,8	27,9	95,3
III $\frac{2,5}{97,5}$	526	1,2	8,6	6,9	29,4	89,2
IV $\frac{5,0}{95,0}$	650	2,4	8,1	7,3	31,3	86,5
V $\frac{10,0}{90,0}$	651	3,8	4,1	7,5	31,2	86,3
VI $\frac{20,0}{80,0}$	651	4,7	2,9	7,6	31,4	86,2
Chernozem						
Initial soil	—	2,6	21,4	1,1	5,2	46,6
I $\frac{0,0}{100,0}$	270	0,1	22,6	0,3	4,9	47,9
II $\frac{0,5}{99,5}$	675	0,4	22,4	0,3	5,0	47,9
III $\frac{2,5}{97,5}$	692	1,7	21,2	0,7	5,0	47,5
IV $\frac{5,0}{95,0}$	707	2,7	20,7	1,2	5,1	47,2
V $\frac{10,0}{90,0}$	719	3,1	20,9	1,3	5,1	47,0
IV $\frac{20,0}{80,0}$	728	4,1	20,6	1,3	5,2	46,6

^aThe numerator indicates the oxygen content, the denominator -- nitrogen in the gas mixture in percentage of volume.

Note: Comma represents decimal point.

that these soils, which have a higher buffer to changes in the reaction of the medium and other properties, are also more stable with respect to the number of aerobic and anaerobic microflora.

The higher the oxygen content in the gas mixture, the more intensely does organic matter decompose in the soil and the more CO₂ is liberated (Table 2). However, it must be noted that in the treatments of the experiment with an oxygen content of 5%, 10%, and 20% O₂, approx-

imately the same amount of CO₂ was liberated both in the sod-podzolic soil and in chernozem. Thus, a decrease of oxygen in the composition of soil gases to 5% (judging by the amount of liberated CO₂) does not produce a decrease of the decomposition of organic matter. Only when there is less than 5% oxygen does a noticeable decrease in the liberated CO₂ occur.

The content of ammonium nitrogen in sod-podzolic soil gradually decreases as the concentration of gaseous oxygen increases, while

the amount of nitrates increases. As known, ammonification may occur under the influence of aerobic and anaerobic microorganisms. This is why an increase in ammonium nitrogen (as compared to the initial soil) was observed in our experiments in the absence of gaseous oxygen (treatment I). Nitrates, on the other hand, not only do not accumulate in the absence of oxygen, but those already existing in the soil disappear. If the soil contains 5% of free oxygen, the amount of nitrates is approximately the same as in the initial soil. Apparently this concentration of oxygen (or one near to it) is the minimum for the nitrification of this soil.

The same behavior of nitrates is observed in chernozem. Here also maximum accumulation of nitrates occurs in the presence of 20% oxygen and the initially existing nitrates disappear almost completely in its absence.

The accumulation of ammonia in sod-podzolic soil differs somewhat from that in chernozem. In the latter no sharp decrease of NH_3 is observed at varying oxygen contents in the soil. In chernozem the total amount of ammonium and nitrate nitrogen remained almost the same in all treatments of the experiment with varying amounts of free oxygen, while in sod-podzolic soil their amounts were lower with higher oxygen contents.

The better the soil is provided with gaseous oxygen the more phosphates available to plants (that is, phosphates of the I and II groups according to Chirikov) accumulate. For instance, in the initial samples of sod-podzolic soil the amount of phosphates of the I and II groups was 38.48 mg, in the sample without oxygen it was 27.35 mg, in the sample with 5% O_2 it was 38.67 mg and in the sample with 20% O_2 it was 39.06 mg.

Conclusions

1. The concentration of free oxygen in soil has a great influence on processes taking place

in it.

2. In the absence of free oxygen in sod-podzolic soil of a moisture content of 60% of its total moisture capacity, the oxidation-reduction potential ($r\text{H}_2$) decreased to 17.6, while at 20% O_2 (of the volume of the gas mixture) it reached 29.4. In chernozem the $r\text{H}_2$ was 19.9 and 28.4, respectively.

3. The transition from aerobic to anaerobic conditions in sod-podzolic soil occurs approximately at an oxygen content in the gas mixture of 5% and in chernozem, at 2.5%.

Increased concentration of free oxygen in the previously mentioned values do not show sharp changes in the quantity of anaerobic microorganisms, in the ferrous oxide, in the decomposition energy of organic substances and in the accumulation of available phosphates.

4. Maximum accumulation of nitrates in sod-podzolic soil as well as in chernozem occurs at the highest free oxygen content, i. e., 20%.

Received November 29, 1959

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PROBLEM OF CALCULATING THE WIDTH OF FOREST SHELTERBELTS FOR EROSION CONTROL

L. I. STARCHENKO

An interesting article by K. L. Kholupyak and A. A. Chernyshev on "New data for the calculation of the width of forest shelterbelts for erosion control" was published in the scientific works of the Ukrainian Scientific Research Institute of Forestry and Agromelioration (No. 8 for 1956). The authors conducted field investigations in forests of the type of dry and humid oak stands on the elevated right bank of the Northern Donets River, above the mouths of its right tributaries, the Uda, Mzha and Gomolysha Rivers. The article indicates that the original riverbanks, where the studies were made, consist of loess-like clay loam, resting on sandy-clayey deposits of the Kharkov stage. The soils are predominantly clay loam, changing into sandy loam in the lower terraces, and alluvial at the bottom of gulches. Most of the forests are typical gulch forests, located in gulches and in places extending over their edges. The description of forests is supplemented by materials from forest management evaluations made by the Zmiyev and Khar'kov Forestries and elaborated in place for the areas under study. The main conclusions of this study lead to the following:

1. Under similar conditions of slope runoff and runoff in the forest an inverse relation exists between loads permissible for melioration purposes (M) and the slope of the area protected by the shelterbelt (i). The steeper the slope, the lower are the permissible loads, consequently, the deeper into the forest does the runoff penetrate along the bottom of the waterway. The relation between permissible loads (M) and slope (i) is expressed by the empirical formula $M = 73 - 253 i$. On the basis of the formula, permissible loads were calculated for forest shelterbelts located at the bottom of a waterway in relation to the various slopes of the bottom of the waterway in the forest.

2. The distance of penetration of the waterway into the forest generally increases with the increasing area of field catchments. However, deviations occur. They are attributable to the fact that the distance to which the waterway penetrates into the forest is influenced not only by the area of the catchment, but also by the slope of the bottom of the waterway in the forest and the width of the stream.

An insignificant influence of the slope and form of a field catchment on loads for meliora-

tion is noted. Loads do not decrease with increasing length of the catchment. On the contrary, loads decrease with decreasing length of catchment, which is associated with the reduction of the time required for runoff to reach the shelterbelt. Each type of waterway bottom in forests has its specific direct relation between the distance to which runoff penetrates and the size of the catchment and the slope of the bottom. It follows that in catchment areas of the same size and under the same slope conditions, field runoff will penetrate deepest into a forest along gulches, less deep along narrow waterways on riverbanks and least deep along the bottom of wide, gently sloping waterways. The article describes conditions under which shelterbelts at the bottom of gulches do not prevent ravine erosion and must be fortified by other measures. In working out these measures, the combination of three major elements must be taken into account, such as the size of the catchment area (F), the slope of the bottom of the gulch (i) and the mean width of the waterway (D). The empirical formula expressing the dependence of the distance of penetration of the waterway into the forest on F and i , has the form $D = (18F + 434i - 53)M$.

The following empirical formula is given for determining the width of forest shelterbelts on the bottom of gulches:

$$D_b = \frac{F}{73 - 253i},$$

where F is the size of the catchment expressed in square meters and b , the width of the runoff stream expressed in meters.

This formula, as the authors point out, may serve as a working formula for calculating the width of shelterbelts for the purpose of holding back most of the field runoff in the zone of the southern left-bank forest steppe. They assume that the difference in the loads would be relatively small for the steppe and forest-steppe regions of the Ukraine, which are similarly dissected, so that the formula presented may already be used for calculating the width of shelterbelts in most of the steppe and forest steppe territory of the Ukraine. In conclusion the authors of the article write: "The new, scientifically based systems of measures for increasing the effectiveness of soil erosion control and shelterbelts for the control of water, proposed and worked out by the Institute, will find wide

application in agricultural and forest melioration."

The article reviewed is undoubtedly of theoretical and practical interest, since it deals with a very important phase of the problem of increasing the yield of agricultural crops and gardens, the improvement of pastures and hay fields and contains useful recommendations and warnings on the calculation of the width of forest shelterbelts for erosion control. However, the article also has certain shortcomings.

One thing draws attention, that the major elements of the erosion control problem — soil, is not examined in the article. It is only mentioned in the general description of natural conditions of the area studied. The forest, as a principal means of erosion control, is also treated without differentiation, as evidenced by the unification of dry and humid oak stands. Because of this the authors do not take into account important biological factors when dealing with the process of runoff and water absorption, and all the erosion control calculations are of a mechanical nature.

K. L. Kholupyak and A. A. Chernyshev propose to calculate the width of water-retention forest shelterbelts on the basis of the geomorphological parameters and runoff channels only. But the absorption of sheet erosion depends also on soil type and texture, on the nature and density of vegetation, on the state of the forest, its

site quality, and the thickness of litter. This is why in the calculation of the width of forest belts for erosion control, biological parameters must be introduced along with geomorphological parameters. If such an approach to the problem is taken, it would hardly be impossible to unify dry and humid oak stands, as it was done in the article reviewed. Another very important drawback of the article is that the authors concentrate their attention only on the calculation of the width of the forest shelterbelts for erosion control on the bottom of waterways. One should not limit oneself to the protection of only a small portion of the shelterbelt area along the bottom of a waterway and calculate the width of shelterbelts in such a manner that all runoff from the field be absorbed exclusively on it. Forest meliorators should be made aware of the measures ensuring the absorption of runoff over as large an area of the shelterbelt as possible and they should be directed to divert runoff from the waterway by means of runoff spreaders and by leveling the edges of forests.

The method of calculating the width of forest belts for erosion control, proposed by Kholupyak and Chernyshev, is only the first step toward a scientifically based approach to the solution of this complicated problem. In order for it to be widely used in practice, additional investigations on the introduction of biotic (soil, litter, herbaceous vegetation) and climatic parameters are needed.

THE PHENOMENON OF IMPULVERIZATION IN THE AREA OF ELISTA

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One of the sources of surface salinization of soil is salts precipitating from the atmosphere. They can be of varying origins: 1) from solid soil particles lifted into the atmosphere by wind; 2) from fine crystalline salt dust, lifted by wind from the shores of salt lakes and solonchaks, or formed after the evaporation of small water droplets lifted from the surface of oceans, seas and lakes; and 3) salts entering into the atmosphere with industrial smoke, and smoke from settlements, or of other origin. Vysotskiy proposed the term impulverization (1, 2) for the phenomenon of "aerial salinization of soil."

The importance of this phenomenon in the salt cycle at the earth's surface and the salinization of soil was pointed out by N. A. Dima, S. S. Leustreyev, Ye. N. Ivanova, and V. A. Kovda (3, 4). The latter stresses the importance of the saline salt cycle in areas in the interior of continents, such as the Caspian lowland.

A large amount of material on the salt content of atmospheric precipitation in the Bashunka, El'ton, Aleksandrova-Gaya, and Novouzensk regions from 1935-1937 is presented by Usov (5). His data show that, on the average, 15 kg/ha of salt a year precipitate in these areas. In spite of this, Usov denies the possibility of the salinization of soil by impulverization, even in semi-arid regions rich in salt lakes. In his opinion, atmospheric precipitation in these areas is mostly purified (5, p. 79). It is hardly possible to contradict Usov on the point of atmospheric precipitation, especially winter precipitation, in these regions generally promotes the desalinization of soil. But in addition to rain and snow, saline fog, saline haze and dust storms are frequently observed in semi-arid regions. These types of impulverization may be of greater importance to the salinization of soil than rain and snow.

Analytical data on the composition of salts in haze and fog are unknown by us. In this respect, the observations made by us on the precipitation of salts from the fog (haze) which occurred on April 11-12, 1955, in the area of the city of Elista in the Kalmyk Autonomous Republic are of interest. It must be noted that during this time of the year dust storms and salt fog are observed over a large territory of the Middle and Lower Volga region (4).

The city of Elista is located near the watershed of the eastern slope of the southern Yergeny. This region is relatively far from salt lakes and solonchaks, which are characteristic of the landscape of the Caspian lowland, where the phenomenon of impulverization occurs frequently. In the region of Elista, the Yergeny hills have an elevation of 150-160 m above the level of the Caspian lowland.

The meteorological situation preceding the fog was characterized by the following. The mean daily air temperature in the last ten days varied from 0.9-6.6 °C. The maximum temperature reached +9.1 °C. Relative air humidity at 1 p.m. varied from 63%-95%. The last rain fell on April 10 and was of a low intensity. It was windy. Easterly and southerly winds reached a rate of 16 m/sec. During the days with fog, the weather was characterized by:

A mean air temperature of 3.6 °C, a maximum temperature of 10.2 °C and a minimum temperature of 0.5 °C on April 11. The relative air humidity was 72%. The wind was from the southeast. The wind rate was 8 m/sec. On April 12, the mean air temperature was 3.8 °C, the maximum was 12.3 °C and the minimum -1.7 °C. The relative humidity was 63%. The wind was from the southeast at a rate of 12 m/sec.

The first evidence of fog was noted at 6 a.m. on April 11, 1955. The fog reached its maximum intensity toward 4 p.m.

The people who were outside found their faces wet and tight. They had a bitter-salty taste in their mouths. The visibility during maximum fog was 4-5 km. The fog dissipated toward 5 p.m. on April 12, 1955. After the fog had lifted, vegetation was covered on the windward side with an ash-gray crust (film), the thickness of which averaged 0.089 mm. The same crust covered the walls and windows of houses facing the southeast. On the lee side the crust was absent both on the vegetation and houses.

In the plowed field, all soil clods raising above the surface were also covered with an ash-gray film on the windward side. We collected the deposit which had formed in two hours on a mirror exposed in the field on April

Table 1

Analysis of the water extract from soil crusts

Sample	Results of the analysis of the water extract ^a							
	Solid residue, %	Alkalinity		Cl ⁻	SO ₄ ⁼	Ca ⁺⁺	Mg ⁺⁺	Na+K (by difference), meq
		CO ₃	HCO ₃					
Soil without the deposit from the fog	0,065	None	0,016	0,004	0,473	0,008	0,008	None
Soil covered with the deposit from the fog			0,262	0,11		0,35	0,49	
	0,654	"	0,018	0,009	9,84	0,100	0,029	2,95
			0,295	0,25		5,01	2,42	

^aNumerator — in percent; denominator — in meq.

Note: Comma represents decimal point.

12, 1955. Scraping off the deposit took some force. The estimated accumulation of the deposit amounted to 0.2 g/hr on a surface of 1 m² exposed to the wind, which amounts to 70 kg per hectare for the entire duration of the fog (35 hours). The estimated amount is low, since we began to collect the deposit only the second day of the fog, when its intensity had already lowered. An analysis of the deposits collected from tree branches and trunks showed that it contained 47.4% of water-soluble salts and 52.6% of insoluble solid matter, 16.3% of which consisted of organic matter and carbonates.

Unfortunately, the small amount of deposit collected did not allow particle-size analysis. The water-soluble salts consisted of 90.6% sulfates, 7.4% chlorides, and 2.0% bicarbonates. Among the sulfates, sodium sulfate predominated (83.5%), the rest consisted of alkali earth cations. Thus, 25 kg/ha sodium sulfate was deposited on the soil surface during the fog, which lasted only 35 hours.

It was interesting to determine how the deposit from the fog had affected the salinization of the soil. For this we collected the crusts on the day after the fog from the surface of the plowed, highly solonetzic light-chestnut, silty clay loam which was covered by the deposit from the fog. Also, crusts unaffected by the fog were collected. From the samples collected, the standard 3-minute water extract was made. The results of the analysis of the water extract, reduced to 100 g of absolutely dry soil, are given in Table 1.

The data show that the deposit from the fog increased the amount of water-soluble substances in the soil ten times (in terms of dry residue). As it might have been expected, salinization was most intense by sulfates.

However, the amount of water-soluble sodium (2.9 meq/100 g) was less than expected, judging from the results of the analysis of the pure deposit from the fog, in which sodium sulfates predominated. It is possible that this is associated with the exchange of sodium for adsorbed soil cations, which could have taken place under natural conditions, as well as at the time when water extracts were prepared. The considerable amount of water-soluble calcium and magnesium salts in the water extract from soil crusts with the deposit from the fog is probably due to these reactions.

The data indicate not only that the salinization of soil by imperviousness is real, but also that solonchaks may take place even in such areas which are at a considerable distance from salt lakes and solonchaks.

Received May 20, 1959

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REVIEW

RECLAMATION OF VIRGIN LAND IN THE SEMI-DESERT

S. K. CHAYANOV

In 1958, the Agricultural Press issued a new and very valuable book: "Reclamation of virgin land in the semi-desert."

The author of the book was one of the first to study methods of reclaiming virgin land in the semi-desert zone of Western Kazakhstan. Fifty years ago he organized the Temir experimental field (now the Aktyubin Agricultural Experiment Station), where many interesting experiments were conducted on the growing of various agricultural crops and forest shelterbelts. The Temir experimental field was the first scientific-research establishment in our country to publish works on the reclamation of virgin lands, on soil investigation, on the climate of Kazakhstan, and on the agricultural practices for dry-land agriculture.

At the present time, the virgin lands of semi-deserts are being reclaimed on a large scale, this is why it would be very profitable for many agricultural workers to get acquainted with the contents and conclusions of this book.

It is interesting that after half a century the author again had the opportunity to be in these regions and to continue certain experiments and investigations. The author had the opportunity of comparing "what was and what became" of the fertility of soils and forest belts, and also of the influence of certain agricultural practices of dry agriculture on yield. "The results of the investigations showed that the light-chestnut soil changed into dark-chestnut soil from 1909-1956 under the influence of forest belts (elaegnus) and other agricultural practices. The humus content in it increased from 1.8% to 3% and the thickness of the humus horizon increased by almost 18 cm."

The author lends a great importance in such improvement of soil to alfalfa, which yielded annually for twelve years 34-40 cntn/ha of high-quality hay where snow retention was practiced. After plowing and working over the alfalfa, grain crops yielded from 26-28 cntn/ha, whereas without snow retention and without alfalfa the yield in plowed fields was only 8-10 cntn/ha. The author of the book reaches the conclusion that with rational melioration soil fertility can be progressively built up and the yield of agricultural crops increased.

S. K. Chayanov studied changes in plants

which occurred in fifty years on a virgin plot with medium clay loam, light-chestnut soil. He found that during this time the Aktyubin steppe became more and more desert-like. The sheep's fescue — feather grass and sheep's fescue — wormwood vegetation, characteristic of soils of the light-chestnut subzone of the chestnut soil zone, which prevailed here at one time, had been replaced by Kochia — wormwood vegetation, which is characteristic of brown soils.

The thickness of the humus horizon decreased by 6-8 cm and its color became light-brown, the depth of effervescence increased to 12 cm, the prismatic B horizon became more pronounced, and the number of solonetz spots in the A horizon increased from 5% to 20%-25%.

S. K. Chayanov gives many data obtained at the Temir experimental field, which are not only not obsolete, but which are even more valuable because of the reclamation of new virgin lands and in particular of complex soils with solonetz spots. He studied rapid methods of desalinizing and reclaiming solonetz and of creating uniform plowed fields. By comparing the dynamics of soil moisture in light-chestnut clay loams and in columnar solonetz, the author found that under virgin conditions columnar solonetz becomes more and more salinized. To stop salt accumulation and reclaim them, he proposes first of all that the impermeability of the B horizon be destroyed by deep plowing and then that the salts accumulated in the solonetz be leached into the subsoil.

This could be done within a period of a few years under conditions of dry-land agriculture by using appropriate agricultural practices: by using manure mixed with hay (cuttings); by snow retention; by autumn following with windbreaks, worked over with cultivators with knife-like blades; and by sowing winter crops and undersowing them with alfalfa, etc. By using this system, high yields of hard wheat were obtained on alfalfa beds. The author believes that a great role in the reclamation of solonetz is played by forest belts in conjunction with windbreaks. He also considers T. S. Mal'tsev's method as being promising for the desalinization of columnar solonetz, for adding new soil, and also for adding gypsum by deep plowing to utilize the gypsum contained in horizons underlying the plowed layer.

The author lends exceptional importance to alfalfa as a biological desalinizer of columnar solonchets. However, he thinks that under normal conditions of semi-deserts, alfalfa plantings give low yields, which is uneconomical. In his opinion, it is more profitable in these regions to sow annual herbs, such as corn and sorghum, and blue alfalfa when snow retention is practiced. It must be mentioned that the author is apparently not entirely right. The cultivation of sorghum and, particularly, joughara which withstand sowing on salinized soils is well known now. The Aktyubin Agricultural Station is widely introducing this crop in its region.

The author clearly underestimates yellow alfalfa, which grows wild in these regions. The work of the Orenburg Scientific-Research Institute of Animal Husbandry (V. Yevseyev), the Krasnokutsk Agricultural Experiment Station, the Kinel' Breeding Station and other establishments showed the effectiveness of sowing yellow and yellow hybrid alfalfa in arid regions with solonchetic soils. The latter has a longer life-span and is more drought resistant. It has now also been established (Kuybyshev Agricultural Institute) that the best effect on the properties of soil is obtained by such herbage mixtures in the root remains of which small roots (less than 1 mm) predominate. In this respect yellow and hybrid yellow alfalfa stand in first place among legumes. The wide experience gained at crop testing stations in the arid zone of the USSR confirms the greater stability of the yield of yellow alfalfa as compared to blue alfalfa. An important role is also played by wheatgrass, especially desert wheatgrass, in the reclamation of solonchets soils.

We should not fail to note the valuable statements made by the author of the book about the immediate necessity of erosion control during the reclamation of virgin lands, especially on weakly sodded soils consisting of coarse-textured soils which rapidly lose their natural fertility. He proposes, as the most effective measures, the establishment of shelterbelts, cover-strip and special erosion control crop rotations with perennial grasses. He also considers as necessary the establishment of bufferbelts of annual and perennial grasses, or tall stubble left after the harvest of grain crops. The soil in virgin areas must be tilled differenti-

ally, taking into account the type of soil and the time it is meant to be used. The author rightly notes that "... the unjustified increase of the depth of plowing of once-tilled and trice-tilled land is nothing else than a waste of the fertility of virgin land."

In the conclusion of the book, interesting and convincing data are given on those great changes which took place in 5-10 years in the agriculture and living conditions of settled areas in the Aktyubin Region, where he began his work half a century ago. Along with millet, which covered 91% of the area under crop, spring wheat is now being widely grown. Yield during the period from 1900-1906 was very low with 4 ctnr/ha of millet, 3 ctnr/ha of wheat, and 2 ctnr/ha of oat.

In 1956 the yield of wheat in the kolkhozes of the Dzhusun district of this Region was 10 ctnr/ha and that of barley in the Emben sheep sovkhoz 14 ctnr/ha. The living conditions of the population also changed greatly. Individual farms disappeared and now the only form of farming is community farming, i.e., kolkhozes or sovkhozes. The former immigrants, which were moved here in 1909, are now wealthy collective farmers. They produced experienced leaders who taught agriculture under severe desert conditions. The income of the kolkhozes ensures high wages and seeds and forage for cattle for two years. Thus, the holding out of agriculture against catastrophes is fully guaranteed.

A great role in this wonderful success was played by the Temir Experimental Field, the humble work of which was the beginning of the reclamation of semi-deserts of Eastern Kazakhstan.

The book is written in simple, popular language and, in spite of the fact that it gives a large amount of scientific-experimental data, is easily read. It would be very good if other older scientists, the first organizers of agricultural experimental institutions and schools, would write books similar to that of Professor S.K. Chayanov. It is especially important as far as pre-revolutionary experimental institutions are concerned which were organized in remote corners such as Siberia, Kazakhstan, the Far East and other regions of our great country.

Reviewed by S. Molchadskiy

OBITUARY

IVAN FEDOROVICH STRANSKIY (APRIL 18, 1886—OCTOBER 29, 1959)

Bulgarian soil scientists have lost their old comrade and teacher, one of the founders of soil science in Bulgaria, the founder of the Soil Institute of the Bulgarian Academy of Sciences, Academician Ivan Fedorovich Stranskiy.

Stranskiy was born in the family of a high school teacher who obtained his education in Moscow. His mother was Russian. Ivan Fedorovich graduated from the Natural Sciences Faculty of Kiev and Moscow Universities with the degree of Candidate of Sciences. In 1914 he graduated from the Moscow Agricultural Institute (Timiryazev Academy). In Russia he attended lectures by D. N. Pryanishnikov, V. R. Vil'yams and N. Ya. Dem'yanov, with whom he was closely acquainted and with whom he corresponded for many years after his return to his country. His long stay in Russia drew him close not only to Russian science, but also to the Russian people, to whom he devoted a number of articles.

The wide general and agronomical culture of Ivan Fedorovich made him interested in many things in the field of agriculture. These interests found application in organizational work for the establishment of the Chair of Agriculture (soil science, soil cultivation and fertilization) at the Agronomical Faculty in Sofia, which he led for thirty years, and the Soil Institute of the Bulgarian Academy of Sciences, which he headed for twelve years.

The liberation of the Bulgarian people from the tyranny of capitalism and facism, created conditions for the intense rise of Bulgarian science and the cooperation with leading Soviet soil scientists. In 1947, Academician Stranskiy took part in the Soviet-Bulgarian soil expedition, which gave the correct definition of the soil groups of Bulgaria and established the principles of their distribution.

The creative activity of Ivan Fedorovich is vast and varied. It carries the stamp of the biological trend in agronomy and the genetic trend in soil science.

In 1926, Stranskiy published his work "Crop rotation with unoccupied fallow in the Pleven district," in which, in contradiction to the governmental view, he proved that a two-field rotation of crops and not a three-field rotation

existed in Bulgaria. In 1933 he was the first in Bulgaria to investigate smolnitses, a very diversified and specific soil type of Bulgaria. Stranskiy published several works on smolnitses and continued to be interested in them to the end of his life. He believed that smolnitses developed under the influence of water, creating meadow or bog-meadow processes. His opinion is substantiated by certain later investigations by Bulgarian soil scientists. Other works of his are devoted to cinnamon-brown forest soils of Bulgaria.

Ivan Fedorovich wrote the first generalized work on the state of knowledge of Bulgarian soils ("Soils" in the Collection of the Economics Institute, Sofia, 1936), as well as a survey published in the East German Republic ("Bulgarian soils and their characteristics," 1955). In 1936 his review "Cartography of Bulgarian soils" was published.

The first Bulgarian geographic net of field experiments with fertilizers was organized by him in the 1920's. He was especially interested in the fertilization of tobacco, the plant which is so important for the Bulgarian national economy.

"The nitrogen balance of Bulgarian agriculture," the only work on this theme in Bulgaria, was published in 1954.

In his writings and lectures, I. F. Stranskiy created a great part of the Bulgarian scientific terminology in the field of soil science and agronomy. He worked a lot on the problem of introducing crop plants in Bulgaria. For a number of years he collected material on the distribution of weeds in Bulgaria. One of his last works was devoted to the effect of man on Bulgarian soils from the time Bulgaria was first settled to the present.

He published a great number of popular and scientific-popular articles in the field of agronomy. All are written with a great erudition and a love for his field of study.

To the last, I. F. Stranskiy kept contact with the scientists of other countries. In 1956 he gave a lecture on Bulgarian soils at the Rumanian Academy of Sciences in Bucarest. In 1958 he took part in the Congress of Soviet Soil Scientists in Moscow and gave a lecture on

the problems facing Bulgarian soil science. The same year he was elected honorary member of the Soil Scientists' Society of the USSR for his services in the field of soil science.

him the high medal "Kiril and Mefodiy" of the first order.

To his last days, Ivan Fedorovich worked on the realization of many creative ideas and plans. He left many works in the form of manuscripts. In 1956, for his services to Bulgarian science, the government awarded

Collective of the Soil Institute
of the Bulgarian Academy of
Sciences, and Editorial staff
of Pochvovedeniye

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